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ABSTRACT

This study shows that generally-held sexist attitudes may be partially responsible for the imbalance between girls and boys at the tertiary level in mathematics. In the first chapter, six criteria are listed for checking to see whether there is sexism. Chapter two reviews selected literature where research findings indicate that girls tend to avoid mathematics more than boys, when given the chance. The third and fourth chapters examine whether girls seem to be less capable, in general, of studying mathematics, or if females are less inclined to do so because of external factors. Chapter five concludes with a summary of the basic findings and a collection of specific recommendations at all levels of decision making in the teaching of mathematics. (MP)

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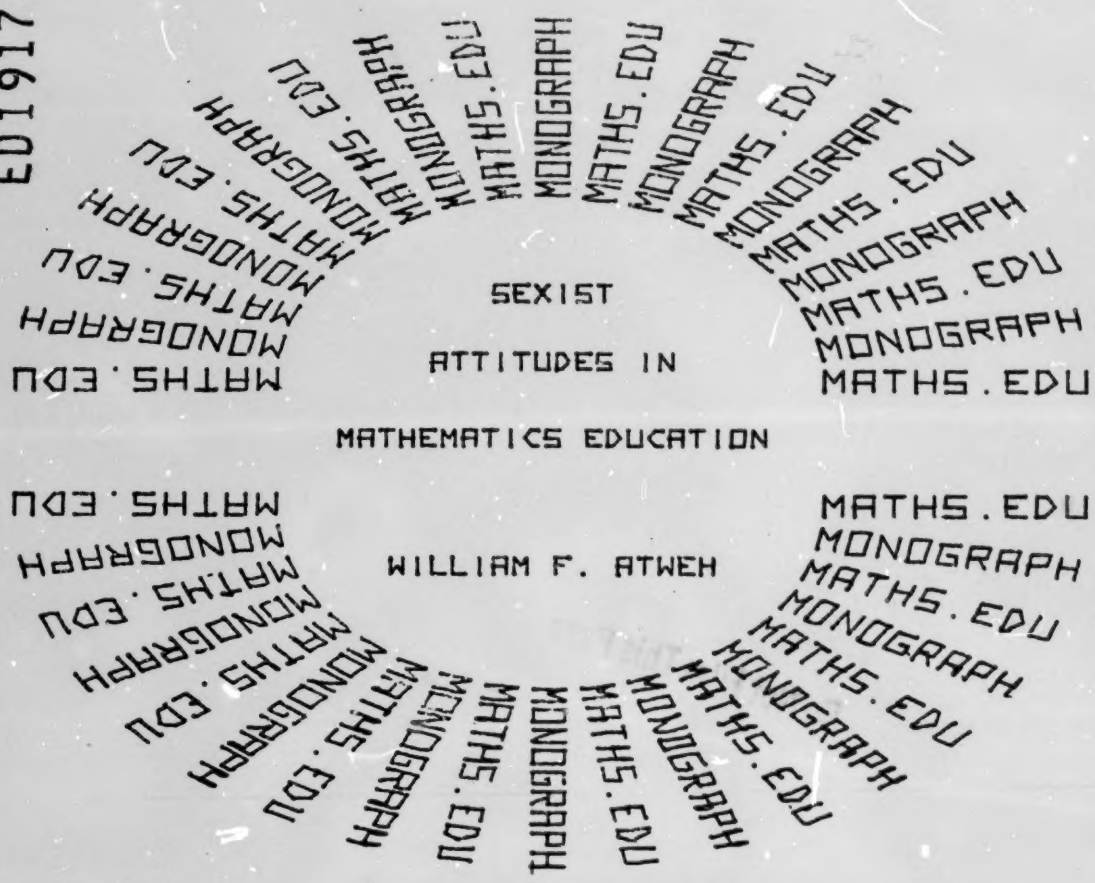

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MATHEMATICS EDUCATION MONOGRAPH

SEXIST ATTITUDES IN MATHEMATICS EDUCATION

WILLIAM F. ATWEH

MATHEMATICS DEPARTMENT

KELVIN GROVE COLLEGE OF ADVANCED EDUCATION

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To Deema Renee, and the rest of the children,

may they be whatever they want to be .....

Do Not Film This Page

FOREWORD

When Bill Atweh told me he had written a monograph on sexism in mathematics education, I was interested for two reasons: first, because I have recently begun exploring the idea of sexist attitudes in general - defining them and trying to trace their origins; and second, because I am a mathophobe from way back. I had begun to suspect that part of my long-standing problem with maths might be connected with the sexist assumptions which surrounded me as I grew up and which I consequently acquired myself. For a long time I believed that some people simply couldn't do maths, that these people were more often female than male people, and that I was one of them.

I asked Bill to let me read his monograph, which he did. The first thing that struck me from a look at the Table of Contents was the good sense of his topic questions; the next thing, from a look at his prose, the clarity of his style. (Is it fair, I asked myself, for a person who is good at maths to be able to write, too?) Then I began to pay attention to his subject-matter, and found it absorbing - thorough to the point of caution and thus convincing in its arguments, and finally important in its implications.

There are fewer girls than boys in mathematics at the tertiary level, Bill finds, but fewer boys than girls in humanities and teacher education. If, as this study shows, the imbalance may be partially accounted for in the field of mathematics by generally-held sexist attitudes, the same attitudes may be responsible for the imbalance in humanities and teacher education. A study like this one, undertaken with the same objectivity and honesty, still needs to be made in humanities and teacher education, and outside education in all fields where sexual bias determines suitability for jobs. If, as Bill does in his Dedication, we hope that our children "may be whatever they want to be", we know that the "wanting to be" is conditioned by the social attitudes surrounding them. May these attitudes not place unnecessary artificial constraints on our children's choices, or on our own.

Frances N. Oppel
Department of Languages
& Literature

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This monograph would not have been possible without the support of Dr. Calvin Irons, Head of the Mathematics Department at Kelvin Grove College of Advanced Education. Dr. Irons was very generous in passing to me information and references on the subject as he came across them. He also read the first as well as final drafts of the monograph and commented on them. Similarly, he arranged my timetable for two semesters in such a way that enabled me to engage in the research and writing of this document.

I am very grateful to the following people for their helpful comments and suggestions on this document: Dr. Peter Botsman, Ms. Frances Oppel, Ms. Margaret Toohey and Mr. Michael Boyle. Needless to say that the final decision in all aspects of writings was always mine; and hence I assume all responsibility for the errors in style or content. Special thanks for Ms. Elizabeth Flick and Ms. Donna Mustchin for typing the final draft of the monograph.

Bill Atweh

April, 1980

CONTENTS

	FORWARD	iii
	ACKNOWLEDGEMENT	iv
	CONTENTS	v
CHAPTER 1	SEXISM IN PERSPECTIVE AND PROSPECTIVE	1
	Is there Sexism in Mathematics Education?	3
	Outline of the Monograph	4
CHAPTER 2	THE AVOIDANCE SYNDROME	6
	Girls and the Avoidance of Mathematics	7
	Women Studying Mathematics	9
	The Price of Avoiding Mathematics	14
	Summary	17
CHAPTER 3	THE ABILITY CONTROVERSY	18
	Sex Related Difference in Performance: Some Reviews	21
	Sex Related Difference in Performance: Other Studies	28
	Summary	33
CHAPTER 4	OTHER FACTORS	35
	Intrinsic Differences Between the Sexes	36
	Differences in Motivation/Attitudes	38
	Societal Factors	43
	Summary	46
CHAPTER 5	CONCLUSIONS AND RECOMMENDATIONS	48
	A Model for Change	50
	Recommendations	53
	Final Comments	57

CHAPTER I

SEXISM IN PERSPECTIVE AND PROSPECTIVE

Among all those involved in the decision making process in teaching school mathematics there is a shared aim/concern. Whether the decision makers are classroom teachers, textbook writers, curriculum planners, or basic researchers, the common concern is how to teach the largest amount of "usable" mathematics to the largest number of members of the society. The acknowledgement of this fact is very basic for the development of the rest of the monograph. It is naive, however, to assume that this principle implies that everybody needs, or is capable of the same type or amount of mathematics. Perhaps a more appropriate motto to describe that aim is "from each according to their ability and to each according to their needs."

That the aim in teaching mathematics should be to reach the maximum number of people with the maximum possible amount of mathematics is not difficult to justify. In fact it follows from three premises. First, mathematics is needed by the "average" person to face the demands of living in the present society. This need was realized by very ancient societies, and since the present society is steadily getting more mathematized, this is even more true today. Secondly, the mathematics needed to face the complex world could be learned and used by a vast majority of the population. Some learn it with more difficulties than others, but every mentally healthy person is capable of understanding and using some mathematical knowledge. Thirdly, people should be trained in the mathematics they need. Waiting for each individual to re-discover the mathematics they need, when the need arises, defies our educational values and practices. These three facts, joined with our commitment to the principles of democracy, equal opportunity and "fair go", imply the need to teach more mathematics to more people.

One area of mathematics education where the above mentioned aim is most clearly reflected is the diagnosis and remediation of children's learning difficulties. Although interest in this area has escalated within the last few years, the terms "diagnosis" and "prescription" have become part of the vocabulary of mathematics educators at almost all levels of instruction (Irons, 1978).

In a set of guidelines for the preparation of teachers of mathematics set by the Commission on Pre-service Education of the Teachers of Mathematics of the National Council of Teachers of Mathematics (1973), the commission recommends that teachers should be able *"to diagnose and prescribe remedies for common disabilities in the learning of mathematics and to know what tools and techniques are available to help with diagnosis and correction"* (Page 15). This is matched with an equal amount of interest at the research level where numerous studies and programs are underway to develop instruments, profiles, and approaches as well as theories and techniques.

In an opening address to the Research Council for Diagnostic and Prescriptive Mathematics conference in April, 1978, Thomas Romberg presents a rather simplified model for summarizing research in this area. Romberg (in Irons, 1978) identifies four major areas of study in recent publications. Some investigations are concerned about studying and correcting the cognitive processes of children, while others are directed for analyzing problems due to instruction. In a personal communication, Dr. Irons indicated that the vast majority of studies recently reported under the subject Diagnosis and Remediation fall in one of these two types. However, Romberg includes in this area research concerning the motivation of children and their social background as they relate to the learning of mathematics. The present monograph is primarily concerned with some issues related to these two areas identified by Romberg.

In particular, this monograph is concerned with sex-related differences between females and males performance in mathematics and mathematics-related professions. Although many research studies are considered, this publication is not merely a review of literature. It is not the intention to simply determine what the research says or does not say about those differences. Rather, the aim of this monograph is to evaluate the attitudes and practices of all those involved in the teaching of mathematics, based on the conclusions from previously reported reviews and investigations. A survey of the history of mathematics and the western civilization yields many instances of significant achievements attributed to females in both areas. However, as will be documented in the following chapter, the distribution of the achievement of the two sexes is far from being balanced. This imbalance is well documented in other studies. It obviously raises a very serious question. Are females as a group disadvantaged in learning mathematics? The seriousness of this possibility lies in the number of people involved in that group. Females represent nearly, and in some cases more than, half of the population. It is obvious that this presents a significant direct challenge to the assumed aim to teach more mathematics to more people.

Contrary to some beliefs, research on sex-related differences in performance in mathematics, is not scarce. As a matter of fact, a major obstacle facing this investigation is the time limitation to review all publications encountered. It is true, however, that this research is sometimes inconsistent, and fragmentary. Moreover, many studies conducted fail to reach specific recommendations on which decisions should be made; consequently they are of no direct value to teachers in the classroom. In this monograph, the review

of the literature is used as an aid to answer (or attempt to answer) the question "Is there sexism in mathematics education?"

Is There Sexism in Mathematics Education?

There are two complications that need to be considered in answering this question. Firstly, the noun sexism and the corresponding adjective sexist, have in our western culture severe negative connotations. Applying the adjective to describe a person has the same intended degrading effect that calling somebody a communist had during the years of the "cold war". Secondly, the word sexism has come to mean many different things to different people. Even different dictionaries do not attach the same meaning to this word. Further, one can argue that dictionary definitions need not coincide with the sociological usage of the term. The writer is biased against any definition of the word that is based on a single sex. Sexism is not like breast cancer that victimises only the female population. It is the writer's belief that a boy who is "pushed" by parents and advisors to pursue mathematics beyond his ability and needs because of high expectations of him as the boy of the family is, as much a victim of sexism as a girl who does not receive encouragement to pursue her talents in mathematics because of certain role expectations from her.

For the above reasons, in this monograph the terms "sexism" and "sexist" will not be applied to describe persons or attitudes. Similarly, a theoretical definition of the term sexism will be avoided. Both of these principles are possible through the use of an operational definition or criteria for answering the question posed above. Hence, for purposes of this monograph, the answer to the question "Is there sexism in mathematics education?" is in the affirmative if one or more of the following conditions hold:

1. If the members of one sex consistently fail to see that mathematics is relevant for their individual professional preparation, or if they consistently underestimate their ability to pursue its study;

2. If the members of one sex consistently receive less encouragement and guidance to choose mathematics subjects because of their preconceived specific role in the society;

3. If the members of the mathematics teaching profession seem to be more confident in their knowledge about sex related differences than is warranted by empirical findings of research or if overgeneralizations are bsed on selected samples of research findings;

4. If the members of the teaching mathematics profession believe that sex-related differences in performance do, in fact, exist and they do not attempt to raise the performance of the disadvantaged sex;

5. If the members of the teaching profession are not aware of the contribution of social and cultural and other factors to the existence of the sex-related difference in performance;

6. And finally, if the members of the mathematics teaching profession pretend that a problem does not exist with regard to the participation and performance of one sex in mathematics or if they avoid the issue by conforming to outside pressures or conventions.

The rest of the chapter outlines the monograph.

Outline of the Monograph

Chapter II reviews the literature in one area where research findings appear to be consistent and conclusions are definite; namely that girls tend to avoid mathematics, when they are given the choice to do so, more than boys. It is shown that girls tend to choose to study mathematics as electives less frequently than boys in highschool and tertiary institutions, even though they may be as capable as boys of their cohorts. As a result of this avoidance, females in the universities are, as a group, less qualified than males to pursue careers that require mathematical skills. With the increase in female participation in the work market, economic reasons are added to the more basic moral reasons behind this concern. More interesting than documenting this avoidance of studying mathematics is the study of its causes. Are girls less capable in handling the study of mathematics at higher levels than boys, or are they less inclined to do so because of external factors? The following two chapters deal with these two possibilities respectively.

Chapter III deals with the study of sex-related differences in ability and achievement in mathematics. Studies completed with Australian populations as well as those using overseas samples are considered. Due to the vast number of studies available, the chapter depends on the work of other reviewers. Three major reviews are considered, two American and one Australian. In addition, two specific studies that are of particular interest with respect to the populations they examine will be reviewed. It will be demonstrated in this chapter that the research on sex-related differences in achievement/ability is not consistent and

the differences between the sexes, when they exist, are not always very large.

Chapter III concludes by discussing the hypothesis that the sex-related differences observed in some studies on achievement/ability are not sufficient to explain the imbalance in numbers of boys and girls in mathematics subjects or mathematics related careers. Hence, other factors need to be considered that may explain why females avoid mathematics and possibly why they do not achieve as well as males in higher mathematics. Chapter IV deals with some of these factors. The research in this domain is even more fragmentary and findings are less conclusive than the two lines of study discussed in the previous two chapters. However, the importance of these studies lies in casting serious doubts about the validity of simplistic generalizations about mathematical ability as they relate to the sexes. Moreover, these tentative findings have some implications for the practice of teaching mathematics in the schools, which is the content of the last chapter.

Three factors will be identified as possible forces acting against the choice of women to study mathematics. Not all of these factors are necessarily directly related to studying mathematics and not all of them are well supported by research. Basic differences in the biology and psychology of females and males, difference in attitude and motivation and lastly difference in societal conditions in which boys and girls find themselves, will be discussed in this chapter.

Finally, Chapter V consists of a summary of the basic findings and a collection of specific recommendations at all levels of decision making in the teaching of mathematics. Some of these recommendations are found in other sources. Yet others originated from the present investigation and current development in the field of teaching mathematics and women studies.

A final note on the limitation of this monograph is in order. With the possible exception of English language, there is no other subject required for so many varied fields of study or used in so many careers as Mathematics. This justifies the importance of studying mathematical capabilities of those seeking advanced education or professions. However, the limitation of this investigation to mathematics is due solely to the unfamiliarity of the writer with research on other areas. It is highly desirable that other disciplines undertake similar endeavours so that results could be compared and a better understanding of sexism in education becomes possible.

CHAPTER II

THE AVOIDANCE SYNDROME

The profession of teaching mathematics at the beginning of the eighties is facing a variety of pressures that are doomed to shape the content and form of the mathematics taught at all levels for the rest of the century. In addition to the forces that motivated the fundamental changes in the field for the past three decades (meaningful learning, new maths, technological innovations, back to basics, ... etc.) new issues are emerging. A significant pressure facing mathematics teaching in the eighties is the resistance of students, and the public in general, to the learning and using of mathematics. This resistance to engage in mathematical activities is taking many forms. First, many students are avoiding mathematics subjects in high school and mathematics related courses at tertiary institutions. More people are failing to see the relevance of mathematics to their personal goals and aims. It seems that the field is fighting a serious battle against the public's apathy toward the concern of the mathematicians and mathematics teachers (Roark, 1978). This apathy is a two edged threat. It is a direct threat to the practice of the teaching of mathematics when it takes the form of cutting funds for research and scholarships leading toward the study of higher mathematics. Yet, more importantly, it is a threat to the society in limiting the pool of talent requisite for the societal needs.

A second form that the resistance to mathematics learning takes is what has become to be known as Mathephobia. For those students who "dare" to study mathematics, probably out of necessity or pressure, "Math anxiety" and "fear" are usually serious hindrances to success in and enjoyment of the subject. Unfortunately, Math anxiety is a growing problem facing today's mathematics teaching. As Bloom and Bloom (1977) argue, this problem is not limited to any particular sector of the school population, yet some segments suffer more as a result of it. For example, mature age students are sometimes faced with crisis situations when they realize that they have to take one or more mathematics subjects for fields like the social sciences. Such students are *"much more vocal about their fears (than recent school leavers) and less happy about completing a course without*

having a full understanding of the material it contains". (Bloom and Bloom, 1977, p.2.).

The professional literature within the field of mathematics education reflects a deep commitment to study the phenomenon of decline of interest in mathematics and, whenever possible, to suggest remedies. For example, the Conference Board of Mathematical Sciences has dealt with the problem very candidly. This Board is an organization of twelve professional societies including the American Mathematical Society and sponsored by the Mathematics Association of America. A recent report of the Board (in Roark, 1978) presents a grim picture of the profession. According to the report, the enrolment of students in introductory mathematics subjects has not kept pace with the increase in student numbers at the universities. The situation is even worse at advanced level subjects where enrolments have dropped by almost one third between 1970 and 1975. Further, many students who enrol in mathematics subjects are ill-prepared. Much of the discussion at that conference was directed at saving "the public image" of mathematics by challenging some priorities and practices of present day mathematics teaching.

Dealing with this problem of mathematics anxiety is not without a cost to the taxpayer. Many institutions and schools have had to deal with this problem through special programs and clinics. Some institutions in Australia such as Armidale College of Advanced Education (Squire, 1979) and Murdock University (Bloom and Bloom, 1977) have special remedial mathematics subjects for starting students. Other overseas institutions provide a series of subjects, workshops, counselling clinics that are open to all math-anxious students (Wellesley-Wesleyan training program, 1979) at a cost of 57,000 American dollars per annum.

Girls and the Avoidance of Mathematics

The reason that the phenomenon of student's resistance to mathematics learning is discussed above in detail is twofold. On one hand, it shows the extent and seriousness of the challenge it presents to the practice of mathematics teaching. On the other hand, it shows that the problem is not limited to the female population in the schools and society. However, as the present section will argue, the problem is more acute with females. Girls tend to avoid mathematics and exhibit mathematics anxiety to a greater extent than boys.

There were times in the history of our western civilization when women were prevented from pursuing the study of mathematics at higher levels on the basis of sex alone. Ernest (1975) cites the story of *"one of the greatest mathematicians of all times"*, Emmy Noether, who was not admitted to the faculty of mathematics at the University of Gottingen because of her sex. Fortunately, however,

this rejection did not stop her from pursuing her interest and contributions to the field. The reason that her name is not widely acclaimed in the history of mathematics is because she published her lectures under the name of a male colleague, David Hilbert. What is extraordinary about the incident is that it did not happen in the "dark ages". It took place only fifty years ago. Similar direct, and sometimes more subtle, prohibitions across the years may be the prime source of the huge imbalance in the contribution of the sexes to the development of mathematics. Thus mathematics has come to be seen by many as a male endeavour.

This last statement needs some qualification. In a recent article, Edith Lunchins (1979) warns against ignoring, overlooking or hiding the achievements of women in mathematics. This concern is very valid. Through the history of mathematics some considerable contributions are attributed to women, yet very few books on the history of mathematics seem to mention them. More recent publications in this area, however, tend to give women proper credit (Osen, 1974). Moreover, Teri Perl (1979) argues that at the beginning of the 18th century women had a substantial amateur interest in mathematics. This interest is reflected in the number of contributions by women to mathematical popular magazines such as the Ladies' Diary. As a recreational magazine, the Diary was addressed to non-mathematical readers; yet it required a significant degree of mathematical sophistication of which many women were apparently capable. However, due to the fast development of mathematics and its use in male jobs, women felt that they were increasingly excluded from mathematical training and activities. Hence, Perl argues, the stereotype of mathematics as a male domain was an effect of this exclusion and not its cause.

It is obvious that today's situation is very different from the eighteenth century or from that fifty years ago. For one thing, more women are in the work force, and mathematics is needed by them as well as by men. Further, most educational institutions are committed (sometimes by law) to equal opportunity and non-discrimination on basis of sex. However, the situation of imbalance in the number of males and females in mathematics is far from being remedied. Lynn Fox (1976) concludes that even though opportunities exist for girls to be enything they want to be, *"one thing very few girls seem to want to be is mathematically talented"* or employed in professional careers in science or mathematics. (page 347).

There is ample evidence from research showing that the phenomenon of girls avoidance of mathematics is cross-cultural and cross-institutional. The following section reviews various studies reported in the Australian and overseas literature. Before the studies are mentioned, two comments need to be made concerning the data. First, during the last few years, there has been a trend of change in the magnitude of differences between the sexes studying mathematics. Hence data that is older than ten years, for example, cannot be used to draw definite conclusions about the present. Second, the data reported in the various studies/countries is not always consistent in type or magnitude. In other words, different sources do not report data about the same aspects of the various

populations, and the magnitude of the data may vary from one population to another. In spite of these two limitations, whatever data is available tends to be consistent in direction in showing that boys outnumber girls at all levels beyond grade 10 of the high school. There seems to be few diversions from that pattern. This consistency surmounts the problems of imcompleteness of the data and warrants meaningful conclusions.

Women Studying Mathematics

The most comprehensive study on the role of women in higher education is the Carnegie Commission's report on U.S. campuses that appeared in 1973. The data for the report was collected between 1969 and 1972. In addition to this data, the report studied the trend of changes during the century. The Commission concluded that there has been an overall decline in the representation of women in college and university facultiesin the span from 1930 to 1970. Many events may have contributed to that decline. The Great Depression put emphasis on the employment of men at the expense of women. Similarly, the rapid growth of traditionally male fields of science, engineering and business resulted in more jobs at higher institutions for men. Lastly, the baby boom after the war caused more women to stay home. This trend of decline in representation of women on university faculties might have slowed down and probably reversed in the seventies. Yet the imbalance in the distribution of the sexes in many faculties is still impressive. Unfortunately, the study does not report the percentages of women in the field of mathematics separately. Mathematics is included under the heading of "Physical Sciences" along with the natural sciences, computer science and statistics. The data is, however divided by type of institution. The grouping of institutions is done according to "prestige". Similarly the data is divided according to level of teaching. Table 2-1 summarizes the percentages of women at the successive levels of higher education by type of institution in 1969.

It is interesting to note the following facts from the table. Firstly, women were least represented at higher positions in each category of institutions. Further, the percentages of women at higher status institutions, tended to be lower than those at less prestigeous ones. Thirdly, the percentage of females on the faculty of each type of institution was lower than female students in the corresponding field of study.

Although similar comprehensive data is not available for Australian and British institutions, the partial data published in these two countries reveal similar trends. Anderson and others (1975) reported a rather extensive study on regional colleges of advanced education in Australia. In their report they showed that only 10.9% of the teaching staff at non-metropolitan colleges were women.

Table 2-1

Women as a Percentage of Persons at Successive Levels of Higher Education by Type of Institution in Field of Physical Sciences 1969

Type of Institution	Under-Graduate	Graduate Student	Lecturer	Instructor	Assistant Professor	Associate Professor	Professor
Research Universities	21	11	9	9	4	3	1
Other Universities	23	11	23	22	4	3	1
Comprehensive Universities & Colleges	35	9*	21*	18	9	9	4
Liberal Arts Colleges I	42	100*	31*	27	9	7	7
Liberal Arts Colleges II and Two-Year Colleges	25	-	-	22	16	14	9

* Based on fewer than 50 respondents.

The representation of women was higher on the faculty of colleges that were predominantly teacher education institutions : 23.3%. These figures are not very different for the corresponding metropolitan institutions where the percentages were respectively, 13.1% and 27.1%. The report asserts that this trend is similar to that in Australian Universities. In another study by Bramley and Ward (1976) the percentage of women teachers at Australian universities is given for 1974. The national average of women among university teaching staff was 15.3% with a range of 8.5% to 24.6%. However, when the position of Senior Lecturer was isolated the percentage dropped to 5.1% with a range of 2.8% to 8.6%. Although the above data is not broken down by fields of teaching, it is unlikely to assume that women were more represented in the field of mathematics than in the overall percentages. Lastly, on the British scene Rosemary Deem (1978) remarks that *"the most striking thing about women teachers and researchers in higher education is their numerical rarity"*. She adds, *"even in subjects which at undergraduate level are dominated by female students, women fail to act beyond the level of a first degree and are conspicuous by their absence in the academic profession itself"*. (page 100).

What is the situation with respect to females studying mathematics at the tertiary level? Again the data from the Carnegie Commission is striking. In the period of time from 1930 to 1950 the percentage of girls obtaining a Masters or a Ph.D. degree in mathematics showed a consistent drop. This trend has been reversed in the past twenty five years. In mathematics the percentage of females obtaining a Masters degree rose from 20 to 30 between 1950 and 1970. The same figures for a Ph.D. rose from 6% to 9% (which is still far from the 20% figure at 1930!).

Of all the students receiving a Bachelor, a Masters or a Ph.D. degree the percentages of those specializing in mathematics were 3.5 for males and 2.8 for females. In 1948 both percentages were 1.6. However, when mathematics related subjects are considered, the difference in percentage is much more impressive. For example, in physics the percentages were 1.3 for males and .1 for females; economics 3.1 and .5; business 18.4 and 2.4. Hence, females not only avoid majoring in mathematics more than males, but they tend to avoid mathematics related areas to a greater extent. It is interesting to notice that these fields have a low representation of women in the workforce as well. It seems that females tend to choose fields of study that have higher percentages of females in the workforce and hence provide better employment opportunity for them. This obviously leads to a vicious circle. The fewer women are employed in a field, the fewer girls will see that field appropriate for their sex, and hence, less girls will attempt to specialize in it; which in turn means fewer females will be employed in the field. Certainly this is the story of females in mathematics.

The comparable data for Australian women majoring in mathematics at tertiary institutions is not complete. Yet the patterns of the available data on Australian students is consistent with the U.S.

and British populations. The most comprehensive source of information in this respect is the 1975 report by a special study group on Girls, School and Society to the School Commission (McKinnon, 1975). According to the report, post-school education in Australia is still dominated by males. In 1974 less than a third of students enrolled in the Universities, College of Advanced Education and Technical and Further Education institutions were females. Further, women in these institutions tended to concentrate in the study of humanities and teacher education more than professional and technical areas. For example, females were very poorly represented in engineering, commercial and applied science fields.

The next level of the schools that need to be examined is the population of students at the last two years of high school. In many ways this is a very important segment of the school to study. To start with, it is at this stage that students are faced with many important decisions. First, they have to decide whether to stay in school or plunge into the work field. Second, if they decide to matriculate they have to determine the subjects they will study during those years. This choice is not only dependent on their past experiences and accomplishments but also on their future aspirations. For the majority of students these decisions will set the course of the rest of their lives. With respect to mathematics in high school two phenomena need to be examined. First, there are more male mathematics teachers than female teachers, and, second there are more boys taking mathematics than girls. It is not possible to assume a cause effect relationship between these two phenomena; yet it is safe to assume that they are not unrelated.

Traditionally, high school mathematics teachers are mostly males. Although recent figures concerning this phenomenon are not readily available in the literature there are reasons to suspect that the situation still exists. The available data from Queensland high schools will be reported here. According to the Department of Education in Queensland (1978) there are 1,075 male teachers at state schools classified as Math/Science teachers compared with 347 females. Care must be taken in interpreting this data. Some of those classified as Math/Science teachers, teach science only. Similarly some others classified as General (1344 males and 798 females) teach some mathematics. It does not seem, however, that these factors offset the imbalance reported above. This imbalance between the sexes is also reflected in the area of teacher preparation in Queensland. In the above source it is shown that females in Colleges of Advanced Education outnumber males (2,138 to 804 in 1978). However, the only two courses of study where males outnumber females are manual arts and math/science programs (85 males and no females in Manual Arts and 50 males and 25 females in Math/Science of second and third year students). It is significant to note that this pattern has not changed for the last few years. Hence, it is safe to conclude that the imbalance of the sexes in teaching mathematics at the high school will not be changed in the near future.

The fact that girls take less mathematics subjects at the high school level is a well documented and trans-cultural phenomenon. In an international study comparing twelve countries in mathematics teaching, Husen (1967) observed *"the tendency for a specialist study of mathematics at the pre-university level to become a predominantly male activity"*, (Page 234). The average ratio in the twelve countries of males to females studying mathematics at last year of high school was 3.7. For Australia the ratio was 2.32; for England it was 5.5 and 2.37 for U.S.A. It should be pointed out again that this data was based on school population in the mid-sixties. More recent data from Queensland schools shows, however, that this trend has not been reversed.

In Queensland schools, high school students have a choice between Mathematics I, Mathematics II and Social Mathematics. Table 2-2 summarizes the number of males and females in each subject in the years 1975-1977. It should be kept in mind that Mathematics I and Mathematics II form a sequence of subjects and social mathematics is a non academic terminal subject.

Table 2-2

Number of Females and Males in Three Mathematics Subjects In Queensland High Schools*

		1975	1976	1977
Mathematics I	M	4662	5224	5082
	F	2800	2962	2844
Mathematics II	M	2540	2540	2534
	F	665	618	701
Social Mathematics	M	3	562	1279
	F	2	355	1274

* (Data taken from Board of Secondary School Studies, 1978).

It is obvious from the above data that the ratio of males to females, in 1977, was lowest for the social mathematics (1.0), higher for Mathematics I (1.78) and highest for Mathematics II (3.61). Hence, this data reveals the same pattern observed by the International study conducted in the early to mid-sixties.

The Price of Avoiding Mathematics

Whether high school leavers intend to enter colleges or universities for further study or whether they decide to seek employment, the trend is for them to need better and more extensive mathematical training. We live in an age where "numeracy" is equated with "literacy". That is, the ability to use numbers and think mathematically is of the same importance to many employers as the ability to read and write. In spite of protests from educationalists and teacher organizations, many employers are requiring tests of literacy and numeracy from school leavers seeking employment or apprenticeship (Education Abstract, 1979). In addition to traditionally "mathematical" based careers of engineering, science and economics, mathematics has become an essential tool for other fields such as psychology, education, and sociology to name but a few. Even in the field of mathematics, job opportunities are numerous. In a pamphlet issued by the Mathematical Association of America (N.D.) the following points are highlighted. In the present period of high unemployment, job prospects for those with mathematical qualifications are above average among scientific fields. Further, qualified secondary school teachers of mathematics are still in demand as are people to work as applied mathematicians in industry and government. Likewise, new opportunities are opening in other fields of mathematical sciences such as computer science and operational research.

Unfortunately, while this trend of more fields of employment and higher education requiring more mathematical training is known to the mathematicians and mathematics educators, some students, teachers and career counsellors in schools may not realize its full implications. This warrants further discussion on the amount of mathematics needed to meet the demands of the present quantified society. We shall start with the mathematics required for studies beyond the high school. In a second pamphlet issued by the M.A.A. (1978), various fields of studies are analysed according to the amount of mathematics they require as prerequisite to admission. Although these requirements vary from one institution to another, a trend is noticed that many higher institutions have increased their entrance requirements in mathematics even for fields that have been classified as non-mathematical. Fifty-six fields of study have been identified. All the fields, with no exception, require a minimum of 2 years of high school mathematics. This, typically, includes one year of Algebra and one year of Geometry at years nine and ten. Eleven fields require just these two years of mathematics. Twenty-three fields require at least one additional year above the minimum. Typically that year consists of a second Algebra subject. The other twenty-one fields require four years of high school mathematics. Normally, the fourth year mathematics in grade 12 would consist of pre-calculus mathematics.

The requirements for entrance to Australian higher institutions vary from one State to another. In Queensland the situation is, in effect, similar to the American situation as far as mathematics requirements are concerned. Although mathematics does not play an explicit role in entrance to many Colleges of Advanced Education and Universities, yet, a typical high school graduate in Queensland would have had mathematics up to grade ten. Only during the last two years of high school are students given a choice about taking further mathematics. This, however, does not prevent students who had qualifications equivalent to high school studies from overseas countries, with no mathematics beyond grade eight, from entering many insitutions in Queensland. In general this situation does not happen often and the requirements for admission to tertiary institutions are not very different in the amount of mathematics required from those in the U.S. Whether or not high school graduates have taken mathematics beyond grade ten does limit their options to some field of studies and some institutions. In other words, the amount of mathematics taken in high school limits students' choices on three accounts: type of institution, field of study and degree attained.

Young (1978) presents a summary of all available tertiary courses at Queensland Colleges of Advanced Education and Universities. It is obvious from that review that Mathematics, next to English, is the subject listed most as a prerequisite for many fields. However, this requirement varies according to institutions and level of study. For example, two colleges in Queensland offer a secondary teaching major, Science/Math. Only in one institution, eight units of high school mathematics or science are prerequisite. Similarly, depending on the institution, courses leading to Bachelor of Engineering may require 4, 6 or 8 units of high school mathematics. In the one institution the amount of mathematics determines the degree obtained. For example, at the Queensland Institute of Technology, three units of mathematics are prerequisite for an Associate Degree in Engineering, while a minimum of eight are required for a Bachelor's Degree.

From the preceding facts it should be obvious that the amount of mathematics taken in high school determines to a considerable extent the opportunities for males and females to participate in the various professions. Further, it can be argues that the amount of mathematical training is related to chances of success and promotion in various careers. This is illustrated by considering the profession of Librarianship. Traditionally, very little mathematics is required or needed in this profession. This is probably one of the reasons why many women seek this type of work. However, the key positions in the libraries across the nation are held by men, (Cass, 1973). Is this merely a reflection of sex discrimination? Also, will changes in social biases in the employment of women and/or social legislation of equal opportunity be sufficient to remedy the imbalance? Maybe. However, Cass expresses some doubt about the sufficiency of these measures. He suggests the fact that future libraries will inevitably rely more on the use of computers and mechanized systems of various functions, more opportunities

will be opened for mathematically qualified personnel. Even though one may not agree with Cass's belief that women have less ability in mathematics than men, the facts argued above are valid. Females' chances will be worse in this profession if the trend of avoiding mathematics continues.

The situation described above of low representations of women at high positions in Librarianship professions is not atypical among other careers. In general, females are not well represented in all high status professions and positions, (McKinnon, 1975). In many western countries the trend is toward increasing the number of women in the workforce. In Australia the percentage of working women has increased from 26.6 to 42.2 during the period 1933 to 1974. This increase, however, does not correspond to an increase of women in institutions of higher education. This implies that more women are entering the workforce with less qualifications than their male counterparts. This, along with other social causes, may explain the concentration of women in clerical positions and their low representation in administrative and executive positions.

Is mathematics responsible for this pattern of employment of women? Indeed, it is simplistic and wishful thinking to claim that if women have more mathematical training the imbalance will automatically be resolved. However, as argued above, the amount of mathematics studied does, in many cases, have a filtering effect (sells, 1979) for many women in many fields. In 1972, based on data from the sixties, Martin concluded that *"from the point of view of future high status educational and occupational opportunities, the most crucial differences in qualifications of boys and girls relates to maths and sciences."* (Page 103). There is no indication that this has changed eight years later, or that it will change in the near future.

It can be argued that mathematics will continue to be essential for the improvement of the status of women in the workforce. There are some indications that it will be even more so in the future. For example, it is a well known fact that many women seek teaching as a profession. In Australia, female students dominate the C.A.E. and in particular teacher preparation courses (McKinnon, 1975). However, regarding the present situation of unemployment in the ranks of teachers, the future of this channel for females might be in jeopardy. Should the employment situation for teachers worsen in the future, it is possible that some females will seek other institutions, like the universities that are more strongly male dominated and require higher qualifications in mathematics than C.A.E.'s.

Summary

The discussion in this chapter has considered a serious problem facing the practice of teaching mathematics. This problem stems from the concern that more members of the society are expressing signs of anxiety and avoidance to the study of mathematics. This is particularly concerning since it coincides with another trend of mathematics becoming more essential for participating and success in many careers and professions. Moreover, this chapter has shown that girls suffer more from this avoidance syndrome than do boys. In general, males tend to take more mathematics at high school and beyond than do females.

The discussion above is limited on two accounts. First, the difference between the sexes has been exhibited only in relation to the amount of mathematics studied. The amount of mathematics studied by both sexes is measured by the number of students in mathematics subjects. Nothing has been said about the actual amount of mathematics learned as a result of those subjects studied. "Does One Sex Achieve More In Mathematics" is an equally interesting subject that shall be discussed later.

A second limitation of the above discussion is in analyzing the reasons behind the trend of avoidance. Why is it that females avoid mathematics more than males? We shall identify two reasons, suggested by the literature, that may, jointly or individually, account for this avoidance. On one hand females could be less capable than males to handle mathematical thinking and situations. On the other hand there may be a host of other psychological, educational and social reasons acting against the freedom of females to study mathematics. The next two chapters will deal with the two alternatives respectively.

CHAPTER III

THE ABILITY CONTROVERSY

Are there sex-related differences in mathematical ability?

Any person who has had some experience in teaching mathematics to a group of children, has observed that some children learn mathematics and can apply it to a better extent than others. The occurrence of this phenomenon is almost universal. Under any teaching situation, with any group of children, some children tend to excel relative to others in handling mathematical situations. Many daring assumptions concerning the teaching of mathematics have been made; for example, Bruner's (1963) generalization that *"any subject can be taught effectively in some intellectually honest form to any child at any stage of development"*. However, the assertion that every child could be brought to the same level of performance in mathematics has yet to be made. The natural question that many mathematics teachers want to ask is "what determines these differences in performance of students". Obviously, there are many factors. The literature in education presents many areas which determine performance and on which students differ. Factors such as motivation, inclination, personality, previous experience are but few examples. However, these factors are not sufficient to explain all differences in achievement. A leading Russian Psychologist, V.A. Krutetskii (1976) argues that *"whenever, (the above) conditions being equal, identical exercises and identical teaching methods yield essentially different results, these differences can be explained by differences in pupil's abilities"*, (page 5). There appears to be a general consensus with regard to the existence of this hypothetical psychological construct called "mathematical ability". Yet, beyond this elementary acceptance of its existence, there is little agreement on its nature, origin and methods of its measurement. These issues will be discussed in more detail in later sections.

The next obvious questions that follows in the minds of mathematics teachers and educators concern the means of enhancing that ability in students, or, more elementarily, means of its discovery. In the

literature, this leads to the study of many other factors as they relate to mathematical ability. Is mathematical ability subject to social, racial, class, hereditary and personality variables? Of particular interest to this monograph, is mathematical ability determined by sex? In other words, are the forces that determine the sexual being of individuals related to the forces that determine their ability in mathematics? Alternatively, are the conditions that evolve from being male or female determinants of the nature and magnitude of this ability?

Attempts to answer these, and related questions are not new. Opinions about differential capabilities of males and females date back to the early Greek thought. Similar generalizations are encountered in almost every stage of development of the western culture. During the last century, with the development of psychometrics as a field of study, these questions were considered with "rigorous" and "scientific" methods. Unfortunately, with all the advances in the theoretical knowledge and research findings, educators are still far from being able to answer these questions with any confidence. Many generalizations about this debate remain statements of belief or hypotheses rather than statements of fact.

A review of the literature on sex differences and mathematical abilities yields numerous complications and some serious challenges facing the answer of this seemingly simple question. For the lay reader, it pays to expand on some of these problems before attempting to review the literature. These problems shall be grouped into four categories: *theoretical, logical, practical and moral*. Some comments before considering each category are now in order. First, these categories are not necessarily disjoint and may not be comprehensive. Secondly, these are problems to be faced in answering the question, *"Are there sex related differences in mathematical ability"* at the current stage of knowledge. They do not necessarily apply to the study of ability in general. Further they do imply that they will remain to be problems in the future.

The first group of difficulties facing the answer to the question posed above is *theoretical* in nature. To answer such a question meaningfully, an understanding of the nature of mathematical ability is essential. It is not intended to cover the different issues related to the nature of mathematical ability in this publication. Suffice to point out that the literature is bewildering in the different interpretations and definitions of this concept (Horn, 1976; Krutetskii, 1976). Firstly, it is not clear whether it is meaningful to talk about a general mathematical ability as such or a variety of individual and interacting abilities. Similarly, there seems to be a debate whether mathematical ability(ies) is(are) innate, acquired through genes by heredity, or whether they are acquired by learning. Obviously, whether such abilities are fixed at birth or developed through training have different implications to the philosophy and practice of mathematics teaching. Moreover, the issue whether mathematical ability(ies) should be seen as characteristic of the individual or of the activities that an individual performs is not fully resolved. It has to be acknowledged

that some of the views expressed in the literature on the nature of ability are more authoritative than others. Yet, the fact that there is no consensus on these basic understandings, makes any answer to such questions subject to the interpretation of each individual researcher.

In the educational literature there seems to be a general trend to define mathematical ability operationally. As a psychological construct, it is not possible to measure ability directly. Hence, mathematical ability is studied in the individual solving mathematical situations. This brings about the second source of difficulties in answering the above question, namely *practical* difficulties. Many different measures and techniques have been employed to measure mathematics ability. Many of these measures were developed using different principles and criteria. Hence, the outcomes from these measures are not always perfectly correlated. Naturally, this leaves the mathematics teacher confused about the choice of the "best" measure to employ. In the related area of intelligence testing, there is a living controversy that illustrates the above concern. At the beginning of this present century, intelligence tests raised great interest in educational and psychological testing. At the same time, the existence of sex differences in intelligence was as controversial a subject as is the existence of race difference in society today. It was observed by various researchers that males and females do not perform the same way on those tests. It is important to point out, however, that the difference was not always in terms of total scores, but on individual items. In later developments of these tests, those items that favoured one sex were judged unfair and were eliminated. This, in turn, eliminated the need to have two separate sex norms. By selecting content to minimize sex differences, the performance of the two sexes became identical. Naturally these tests *"are hardly the instruments of choice for studying sex differences"*, (Tuddenham, 1969). Hence, depending on the test construction process, sex differences can be exaggerated or eliminated; and, the choice between the various tests is a legal/moral concern more than an educational/statistical problem.

The third reason why the simple question *"are there sex-related differences in mathematical ability"* can not be satisfactorily answered is because of some *logical* difficulties. It is argued above that being a hypothetical construct, ability can only be measured indirectly by observing the performance of an individual on various tasks. However, the performance on these tasks is subject to other factors such as motivation, previous experience and so on. This is in contrast to other measurements like height or weight. The height of a person can be measured by a ruler with specified units. The measure obtained in this case is independent of the individual's weight, jumping record, looks, motivation or personality. Hence, in ability measurements, in order to obtain meaningful comparisons of two or more individuals, care must be taken to control the other factors that might have caused the differential performance. In the case of sex related differences this fact is not always taken into consideration. It has been

shown in the previous chapter that, in general, males and females do not have the same experiences with respect to studying mathematics. Moreover, it will be argued in the next chapter, that females and males tend to differ in terms of motivation, attitudes and other factors which might account for the differences in performance reported in some studies. Hence, scores on tests should be interpreted with the utmost care when comparing the mathematical ability of males and females.

The last source of difficulties in answering the above question is *moral* in nature. Suppose, for the sake of the argument, that the above problems are accounted for, and that the ability of females and males can be measured systematically and meaningfully. There still remains the question of what to do with the knowledge of sex-related differences. Various educators have pointed out the tendencies of teachers, as well as other curriculum planners, to misuse ability tests. Krutetskii (1976) expresses his concern that, more often than not, ability scores are used to group students into various streams. In many cases, this grouping leads to differential educational experiences that tend to establish and exaggerate the ability differences rather than being used in a remedial sense to provide additional experiences for the less able. In this sense, the measures of ability are used in a "judgemental" way rather than as an "input" into a better and more mathematical training for more students. Unless teachers are very clear and careful about the usage of ability scores, it is dangerous to attempt to answer the above question with a simple yes or no answer.

For all of the above reasons, the original question shall be replaced by a more specific question: *"Are there any sex related differences in mathematics performance"*. In other words, this chapter shall review the literature and research on differences between the sexes in larning mathematics and performing on mathematical tasks without generalizing the observations to mathematical ability. However, it is important to bear in mind that the literature itself is not committed to this distinction. Hence, the term ability will be encountered many times in the coming section. The reader can reach his/her own conclusion concerning the substitution of the term "ability" by "performance". The next section starts with three other reviews of literature on sex differences and consider their conclusions. Two of the reviews, which were completed in the United States, are very frequently quoted and considered authoritative. The third review is one of the few reviews published on Australian studies. The section to follow these reviews will consider other selected findings of various studies that are judged as important landmarks in this area of research and/or yield interesting results.

Sex-related Difference in Performance

Some Reviews

Probably the most extensive review of research on sex related

differences in psychological and education literature is the one done by Maccoby and Jacklin (1974), which is an update of a study they reported in 1967. The review is by no means limited to mathematical studies, yet this discussion of the review shall be restricted to mathematical related studies and conclusions. In their summary of the study, the authors categorize the conclusions into three areas. First, that review helped to dispose of some "unfounded beliefs". These beliefs include:

1. that females are better at rote learning and repetitive tasks where males are better at high level cognitive processes;

2. that males are more analytic in their thinking than females; and

3. that males are visual and females are auditory in their thinking.

In a second category of conclusions, the authors state some sex-related differences that are "fairly well established". This category consist of the following mathematics-related differences:

1. Females have greater verbal ability than males;

2. Males excel in visual/spatial ability;

3. Males excel in mathematical ability.

In a third category, Maccoby and Jacklin identify some areas that are still "open questions". These include anxiety, competitiveness, activity level and aggression, among others. The following chapter will discuss some of these differences is more detail. What is interesting here is to note some of the authors remarks about the above three "fairly well established" conclusions.

1. Verbal Ability - While many research projects have shown that the verbal ability in females develop earlier than that of males, some studies have reported no differences in that ability during the primary grades. Noticeable differences start to appear at about age 11 and female superiority increases throughout the high school and later years. Moreover, this superiority is consistent at high level tasks of comprehension, analogies and creative writing as well as low level tasks like fluency.

2. Spatial Ability - Most studies have shown that the differences in spatial ability start to emerge at adolescence and beyond.

3. Mathematical Ability - Both sexes show the same ability in the acquisition of quantitative concepts and arithmetic skills in the primary schools.

> Between the years 12 to 13 males show superior ability in those skills development. While the magnitude of this superiority varies from one study to the next, this difference in ability is not a function of the amount of mathematics studied alone. Moreover, this difference is not, in general, of the same magnitude as the differences in spatial ability.

Not having access to all the studies reviewed by Maccoby and Jacklin, it is not the intention of this document to evaluate the authors' conclusions. However, it would be illuminating to examine one particular aspect of their data. Without making the assumption that all studies reviewed are equally valid or rigorous, an interesting pattern is noticed when the number of studies used to reach those conclusions is taken into consideration. The authors group the studies into five categories: Spontaneous verbal, tested verbal, non analytic visual, analytic visual and quantitative. Table 3-1 below summarizes the number of studies reviewed in each area. The studies are grouped according to the population of students employed. Moreover, the number of studies showing superiority of either sex is given. The division of the studies in this fashion is not done by Maccoby and Jacklin.

Upon examining only the number of studies within each category which showed superiority of one sex over the other, it seems that the author's conclusions stated above are justified. However, by taking into consideration the number of studies showing no difference between the sexes a slightly different picture evolves. For example, at the secondary group in the combined verbal studies, 20 out of 35 studies (57%) showed no difference between the sexes; two studies showed the reverse pattern concluded by the authors. In other words 63% of the studies reviewed with secondary populations did not conform with the above stated generalization that females are superior to males in verbal ability. In the group of studies dealing with spatial ability, 17 out of 44 studies (39%) showed no difference between the two sexes in the high school samples. And, in the studies dealing with quantitative tasks, 6 out of 20 studies (30%) showed no difference between females and males for the same age groups. While these observations do not necessarily reverse or negate Maccoby and Jacklin's conclusions, they, at least, shed some doubt concerning the generality of the differences judged by the authors as being "well established".

The second source of reviews that we shall consider are those reported by Fennema appeared in 1974. The following year, the author reported a more specific review of literature on spatial ability and mathematics learning. The message from both reviews is the same: sex related differences in mathematics learning are not as clear cut or consistent as previously assumed. Further, during the years 1975 and 1976, Fennema and Sherman carried out two experimental studies on the mathematical performance of highschool and middle school populations. The outcome of these studies seems to be consistent with the conclusions obtained from the two previous reviews (Fennema and Sherman, 1977(a) and 1978).

Table 3-1

The Number of Studies Reviewed by Maccoby-Jacklin Showing Sex Differences by Age by Content

	Primary	Secondary	Both
1. Verbal Spontaneous			
Number of comparisons	24	2	3
Females superior	6	1	1
Males superior	2	0	0
No sex difference	16	1	2
2. Tested Verbal			
Number of comparisons	80	33	18
Females superior	18	12	7
Males superior	10	2	1
No sex difference	52	19	10
3. Visual Ability (non analytic)			
Number of comparisons	21	10	4
Females superior	2	0	0
Males superior	1	8	0
No sex difference	18	2	4
4. Visual Ability-(analytic)			
Number of comparisons	19	34	11
Females superior	3	0	0
Males superior	2	19	4
No sex difference	14	15	7
5. Quantitative (mathematical)			
Number of comparisons	9	20	6
Females superior	3	0	1
Males superior	0	14	2
No sex difference	6	6	6

In the 1974 review, Fennema attempted to investigate whether the assumed male superiority in learning mathematics is a myth or a reality. Many journals in education and mathematics were cited and research studies reported in them after 1960 were identified. Further, the studies selected, were grouped into four broad age/grade categories. In the first category, studies related to pre-school subjects, four studies were identified. Three of the studies (using numerousness, concept of number and other mathematical abilities tasks) reported no sex-related difference. In the fourth study, in the preschool group, females had higher scores on number, geometry and recall tasks. In the second category, studies employing early primary school children, nine investigations were reviewed. One study (problem solving tasks) indicated a better performance by males. Another study reported males superiority on one measure used (space scale). Two studies indicated females superior performance (categorizing items on a number of attributes and mathematical reasoning). In five other studies, involving a variety of measures of mathematical learning, no significant difference resulted. The authors conclusion regarding the studies in the primary school is that there are no consistent significant differences in learning mathematics by males and females in the early primary years.

In a third category, studies using pre-adolescent and early adolescent populations, 20 studies were reviewed which result in a "more confused" picture regarding sex-related differences. It is probably best to quote Fennema in her conclusion:

> *"Although generalizing results from so many divergent studies that analyzed different aspects of mathematics learning hides subtle and important variations, it appears safe to conclude that in overall performance on tests measuring mathematics learning there are no significant differences that consistently appear between the learning of boys and girls in the fourth to ninth grade. There appears to be a trend, however, that if a difference does exist, girls tend to perform better in tests of mathematics computation ... and boys tend to perform better in tests of mathematical reasoning ... "* (page 135).

Further, less decisive conclusions could be reported from studies using secondary school populations. Only three studies within this category had been reported in the journals cited. No sex related difference was found in one study (teacher made geometry test). Males out-performed females in one study (standardized achievement test; and females out-performed males on the third study (Algebra test). However, it can be argued that the population of females and males in these studies might not be similar. It was observed that more low achieving males tend to drop out of high school than low achieving females. Moreover, females chose to study mathematics

to a lesser degree than males. On the basis of these facts and the small number of studies reviewed, it was difficult to reach definite conclusions.

The second review of literature reported by Fennema in 1975, even though restricted in scope to spatial ability, is of particular importance. Sex related differences on spatial ability have always been assumed to exist and are used to explain sex related differences in mathematics learning. Fennema set out to examine these two hypothesis. She indicated that some authors have fallen into the trap of considering spatial ability as a unitary ability. It is argued, rather, that two or more factors contribute to spatial ability. Moreover, recent research has shown that sex differences exist on some of those factors but not others. Fennema traces the development of conclusions reached by Maccoby and Jacklin between the earlier reviews of 1966 and those reported in 1974. In the earlier review, Maccoby believed that males were superior to females in all types of spatial ability starting at early school years. In 1974 her conclusion was changed to male superiority on one type of spatial ability, i.e. spatial visualization, with the difference not appearing until adolescence. Further, Fennema showed that male superiority in spatial ability may not be a cross-cultural phenomenon.

"Although the relationship of mathematical ability and spatial visualization ability appears logical, argues Fennema, empirical data confirming a positive relationship is less clear." Some factor analytic studies as well as reviews were cited to indicate that the question whether the two abilities are interdependent cannot be answered. Even the evidence for a relation between spatial ability and performance in school geometry was not always consistent from one study to another. Just as in the first review, the author concludes by raising more questions that need to be investigated about sex-related differences in the area of spatial ability.

In a two year investigation into performance of high school males and females on mathematics tests, Fennema and Sherman (1977(a) and 1978) set out to investigate the extent of sex differences and its relationship with other non-cognitive factors. The first year study involved four high schools in Madison-Wisconsin. The second study involved nine middle schools, in the same city, that were classified as feeder schools into the four high schools. Three cognitive factors, achievement, verbal ability and spatial ability were tested. Other affective factors were tested using an instrument developed by the authors (Fennema and Sherman, 1976). These variables included: attitude toward success in mathematics, stereotyping of mathematics as a male domain, perceived attitude of mother, father, and teacher toward one as a learner of mathematics, effectance motivation in mathematics, confidence in learning mathematics and usefulness of mathematics. These variables were hypothesized as affecting the sex differences in achievement and/or election of mathematics subjects. In addition to these

variables, a test of problem solving was used in the middle school sample. The test was intended to examine any sex differences on higher cognitive tasks.

The main dependent variable was the score on the achievement test. The independent variables consisted of school, grade and sex. Only in two schools, did males achieve higher scores on the achievement test than females. Similarly, in only two schools did males perform significantly better than females on the spatial visualization test. More interesting than the number of significant comparisons is the pattern in which they evolved. In one of the schools showing boys superiority in mathematics achievement, five of the eight affective variables showed sex-related differences. Males showed more confidence in mathematics, perceived mathematics as being more relevant, perceived their father and mother more encouraging and saw mathematics as more relevant than the females in that school. In the second school where males achieved better, six of the affective variables favoured males. In addition to the above-mentioned five, boys at this school had a more positive attitude toward success in mathematics than females. This is in contrast to 1 and 3 significant differences on the eight affective variables in the other two schools where achievement of males and females were not different. Further in the first two schools, when the affective variables were used as co-variates sex related differences in achievement disappeared. Further, the authors observed that sex related differences, in general, were small and the distribution of scores tended to overlap considerably. The pattern seemed to indicate that the differences in achievement were probably influenced by socio-cultural factors. Finally, in the middle school samples, very few of the comparisons very significant. Not only did females not perform better on computation tasks, males did not perform better on spatial tasks and other high cognitive level tests.

The last review of research that shall be considered was done on Australian literature and reported by Clements and Wattanawaha (1977). Eleven Australian studies were reviewed, seven of which were completed by graduate students at Monash University. To parallel the above reviews these studies reviewed shall be grouped into three categories according to the age of the sample used. Four of the studies employed primary school children. Two of these studies reported no significant difference between the sexes on achievement test and arithmetic problem solving tests. In a third study, males performed better on a space test and on Piagetian solid sectioning test but not on logic and numeration tasks. The last study reported a better performance of females on a logic test but not on spatial and numeration tasks.

In the second group of studies, two investigations employed both primary and secondary school subjects. One study reported no overall difference on a numeration test while the other reported a partial superiority of males on some items of a spatial test. The last five studies reported by Clements and Wattanawaha involved secondary school subjects. Three of these studies reported no sex-related differences on achievement, Piagetian type sectioning solids

and school based assessment. One study reported male superior performance on achievement tests and the last study reported a partial male superiority on two spatial subtests but not on another two. Although the authors make no conclusions regarding this review, it seems reasonable to make the following observations. In studies using achievement tests there seems to be no difference between the sexes that is consistent across the studies. The same is true of studies that use spatial ability tasks. However, when a difference is reported on these later studies, the difference appears in favour of males on some items/subtests used to measure spatial ability.

Sex-related Differences in Performance

Other Studies

As pointed out in a previous chapter, the literature dealing with sex related differences in mathematical performance/ability is by no means scarce. It is not the intention of this monograph to expand upon or update the reviews of literature mentioned above. Since the publication of the two earlier reviews, the western English speaking world has had a chance to read the work of the Russian psychologist, V.A. Krutetskii (1976). Krutetskii's work consists of the most extensive and serious research on mathematical ability. The editors of this work in the United States estimated that Krutetskii will probably have the same impact on mathematics education research as the work of Jean Piaget. In this landmark document (Krutetskii, 1976), a mere two and a half pages is devoted to sex-differences, two of which are reviews of western studies. This apparent lack of interest in sex differences probably reflects the Soviet tradition of assuming that no difference in principle exist in this domain, and that any essential difference is to be explained by tradition, upbringing and education. Based on the empirical data obtained in this study, the author concludes, *"with all certainty that (this research), as well as the studies by (others), did not reveal any qualitative, specific characteristics of mathematical thinking of boys and girls"*, (page 343).

Before leaving this topic, it is important to examine two related issues that will be illustrated by two studies using different samples of students. Most of the studies reviewed above considered the performance of students at various school levels in one or more schools in a single city or school system. Few studies attempted national comparisons such as the National Longitudinal Study in Mathematics Education in the U.S. and the Literacy and Numeracy study in Australian schools. However as Husen (1967) suggests, *"one might even say that sex differences in educational achievement cannot be fruitfully studied unless cross-cultural differences are considered among the independent variables"*, (page 234). If differences in performance between males and females are to be attributed to sex then one would expect to observe two things.

Firstly, the sex differences would be observed independent of the country in which the test is administered. In other words, if males in culture A are superior to the females in that culture on a certain measure, then the same should be observed for males and females of culture B. The statistical term for this phenomena is that there is no sex by culture effects interaction. This, by itself, is a necessary but not a sufficient condition for any generalization on sex related differences. Secondly, if the differences in performance are to be attributed to sex, then if males of culture A are superior to the females in that culture, they also have to be superior to females in culture B.

The statistical concept of interaction is crucial to understand the above points. For the statistically oriented reader, any standard text on experimental design and analysis (for example Kirk, 1968) is recommended for explanation of this concept. For others the following paragraphs will be sufficient to illustrate the above two hypothesis. Whenever two factors, say sex and culture, are hypothesized to effect performance on a certain task, the five patterns shown on Figure 3-1 may arise.

In graphs a-1 and a-2 the differences between the two sexes in both cultures are the same. Statistically, there is no interaction between the two factors of sex and culture. In all other cases this is not true. In the case of graph b, while females of culture A are superior to their male counterparts the reverse is true for culture B. Similarly in case of graphs c-1 and c-2, while one sex is definitely superior to the other in culture A the difference is not so big in culture B (graph c-1) or is reversed slightly in culture B (graph c-2). Statistically, in the last three graphs the sex factor and the culture factor interact with each other. In all three cases it cannot be asserted that one sex is necessarily superior to the other since this statement varies from one culture to another. However, a closer look is needed at the difference between situations in graphs a-1 and a-2. While in both graphs, statistically, there is no interaction, there is a subtle difference between both cases. While in both cases the males are superior to the females or that particular measure, in graph a-1 the females of culture B are superior to the males of culture A. Hence, only in case of graph a-2 the claim that the difference of performance on that task is caused by sex alone can be justified.

The international study of Achievement in Mathematics conducted by the International Project for Evaluation of Educational Achievement, which is affiliated with UNESCO, furnishes some insight into the above patterns. The study involved twelve countries around the world. Four samples were chosen from each country.

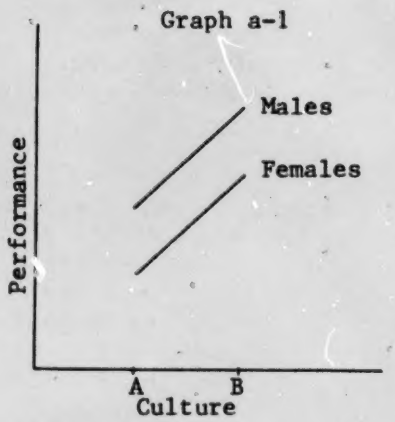
Population 1a - All pupils who are 13.0 - 13.11 years old at the date of testing.

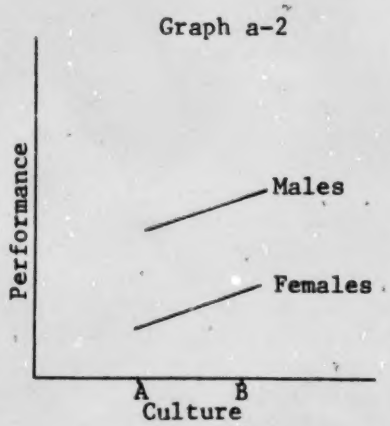
Population 1b - All pupils at the grades level where the majority of pupils of age 13.0 - 13.11 are found.

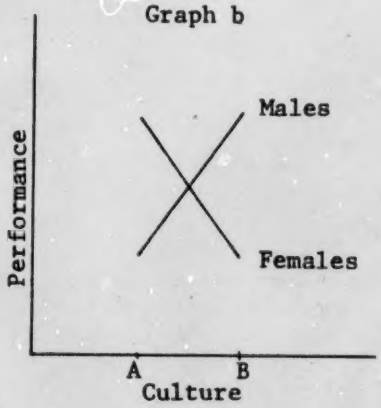
Population 3a - All students at terminal pre-university

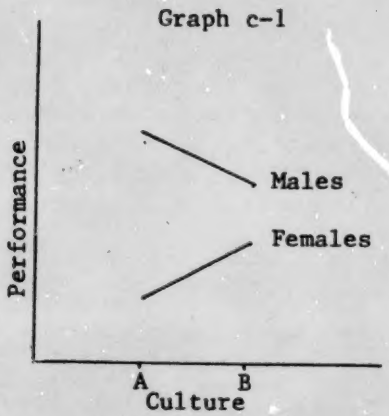
Figure 3-1

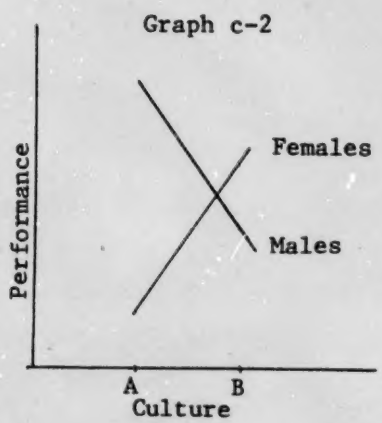
Possible Sex by Culture Interation Positions











high school grade who study mathematics as an integral part of their course.

Population 3b - All students at terminal pre-University high school grade who study mathematics as a complementary part of their course and all others.

An achievement test as well as attitude scales were administered to all samples chosen. Moreover, the achievement test had some items classified as verbal problems and others classified as computational.

The overall analysis of sex differences on all measures with all populations seems to be rather consistent and sometimes unexpected. On all three measures: total score, verbal problems and computational problems, the males in all four populations score significantly higher than females. The same results were obtained on the attitude scale. These results are not necessarily identical with studies reported above. However, the main contribution of this study is the observation that, in all populations the interaction beween sex and culture was significant. That is sex differences are not constant across the various cultures. This necessitated the study of those differences in each country separately. The results obtained showed that countries varied greatly on the patterns of superiority of males on the three measures for the four populations. In the case of one country, males maintained their superiority on all measures of all populations. In other countries, including the U.S. and Australia, none of the twelve comparisons were significant. In some countries, a slight male superiority on computational problems as well as total scores was noticed. Lastly, it was noticed that sex difference was a within-culture phenomenon. That is, although the females of one country were lower in their mathematics achievement than the males of that same country, there were a number of countries where the inferior females were superior to males of other countries. In terms of the graphs in Figure 3-1, graphs a-1, c-1 and c-2 seem to apply. Unfortunately not enough information is available in the study to indicate the frequency of each appearance. It is clear, however, that although in none of the countries, populations and measures do females achieve a significantly higher score than males (graph b), the occurrence of the other three types of graphs (a-1, c-1, c-2) seem to indicate that factors other than sex need to be considered in interpreting the results. It is not exactly known what factor(s) in the various cultures is (are) responsible for these variations. Is it social values, selection of students, or educational systems? In any case, the claim that females achieve less in mathematics than males, *because of their sex,* can be easily challenged.

The last issue that needs to be discussed in this chapter is the variability between performance of females and males on mathematical tests. One consistent observation noted from the international study reported above, is that males showed greater variability in their performance than females. That is, the spread of scores on most tests used with males is wider than that of females. It has often been stressed in the literature that the distribution of

scores of both sexes have great overlap. Many males perform better than the average female; yet the opposite is also true. This implies that new insights can be gained through studies that deal with more specific populations of students, the highly able or gifted students for example. Such studies are important for two reasons. Firstly, many studies showing significant differences in performance between males and females used students of above average ability. It has been suggested that the performance of males of very high ability may contribute to the overall superiority of males on solving mathematical problems (Schonberger, 1978). Secondly, concentration on the highly able population may add new insight to the nature of ability in general (Krutetskii, 1976) and show how mathematical ability can be fostered (Fox, 1976).

The Study for Mathematically Precocious Youth (SMPY) at John Hopkins University furnishes such a study of highly able students. The study began during the fall of 1971 by searching seventh, eight and young-in-grade ninth grade students for precocious students in mathematical reasoning ability as measured by the Scholastic Aptitude Test - Mathematics (SAT-M). The search was conducted during 1972, 1973 and 1974 school years. Students with high scores on school based achievement measures were invited to sit for the SAT-M test. In all three years more males volunteered than females. Similarly, in the three years, the study had identified many more males than females as being highly precocious mathematical reasoners. The highest score was consistently held by a male with up to a difference of 190 points between highest score for both sexes. The ratio of males to females who scored above 660 was 16 to 1 compared to the overall ratio of participants of 1.4 to 1. The differences in the distribution of the two sexes was most striking at the upper end of the score scale (Fox, 1976).

The second part of the study is equally illuminating. To evaluate the hypothesis that precocious achievement in mathematics can be directly influenced by environmental factors, the study planned accelerated classes during the summer of 1972 for selected students who had finished the sixth grade. The following year the classes were repeated for another group of eighth graders. Although these classes were highly successful in promoting precocious achievement in mathematics among males, they were far less successful with females. It observed that less females were eager to enroll in such a program and more of them tended to drop out of the classes before their completion. Upon interviewing the girls who decided against completing the program, a general reluctance and fear was noticed to become accelerated in their school placement. Many were concerned about the negative social consequences for them in the schools.

Based on the above observations and on the feeling that girls tend to reveal more interest in social than theoretical activities, a second program for acceleration was planned specially for girls. The new program emphasizes social co-operation rather than competition and is taught by women. Men and women scientists are invited to speak about various possibilities of employment in

mathematics and science. This approach to the acceleration program proved to be considerably more effective in accelerating females in school mathematics than the previous scheme. This approach however, did not promote the same extent of acceleration for females as the other program for males. The author argued that although it might be more difficult to foster high achievement in females than it is with males, this study had shown that under the right conditions females high achievement can be extended considerably.

Summary

This chapter has considered some aspects of performance of males and females on mathematical situations. To avoid various problems that remain insoluble given the current knowledge, the question of sex-related differences in mathematical ability has been avoided. Instead the discussion is directed toward investigating sex related differences in performance or achievement in mathematics. All three reviews of research mentioned seem to indicate that the differences between the two sexes are not as consistent or as large as many people claim. The international study reported, confirms the observation that differences between the sexes is a function of cultural variables as well as possible sex related factors. The effect of environmental factors on high achieving girls is stressed by the results of the last two studies mentioned (Husen, 1967 and Fox, 1976).

To conclude, the results of this chapter have to be taken in conjunction with those of the previous chapter. It was shown earlier that females avoid the study of mathematics to a larger extent than males. The present chapter attempted to test the hypothesis (a) that the ability or achievement of females in mathematics is lower than that of boys and (b) that this lower ability/achievement explains the imbalance of numbers between females and males in mathematics classes at the high school and tertiary levels. The following discussion is mainly concerned with the latter hypothesis. Three arguments could be presented, and supported by research, against the validity of that hypothesis. *Firstly*, sex related differences in achievement in mathematics are not always consistent or universal. The magnitude of these differences seem to vary with cultural (Husen, 1967) and school (Fennema and Sherman, 1977(a)) factors. However, as documented in the previous chapter the avoidance syndrome is more universal in the western culture.

Secondly, in many reported studies differences in achievement between the sexes is not as large as the difference between the representation of the sexes in school mathematics. It has been shown by many studies that the distribution of abilities of the males and females tend to overlap. Further, in certain cases the within sex differences are as large as the between sex differences.

Yet, as Sherman and Fennema (1977(a)) have shown, in the sample of low ability students, more males decided to take further mathematics subjects than females. Hence, ability alone is not the sole determinant of further study of mathematics.

Thirdly, the sex related differences in ability/achievement reported in many studies tend to appear at higher grades at the same time that the avoidance phenomenon is observed. It seems likely that both phenomena are caused by one or more factors rather than one causing the other.

These three arguments taken in unison seem to shed some doubt on the validity of the hypothesis that sex related differences in achievement/ability is the sole reason of the imbalance of the sexes in higher mathematics. Hence other factors need to be examined for their relation to choice of females to avoid mathematics. This is the content of the next chapter.

CHAPTER IV

OTHER FACTORS

The phenomenon that this monograph sets out to investigate is that females are not well represented in the study and teaching of mathematics. Concern about this phenomenon stems from the facts that females need more mathematics to face the demands of present society and the job market (Chapter II) and that they are capable of studying more mathematics (Chapter III) than is currently available to them. If this is indeed the case, then the question *"why don't females study more mathematics"* is a pressing one facing the education community in particular and society at large. The previous chapter of the monograph concluded by presenting various reasons why the phenomenon of females' avoidance of mathematics cannot be explained completely and solely by the ability hypothesis (i.e. that females as a group are less able to study mathematics than males). Hence, other factors need to be examined to get a better understanding of the many facets of the problem and its causes.

There are several "other factors" that have been identified in the literature as possible causes for the avoidance of mathematics by females. Due to the lack of a standard model for studying these varied factors, this chapter will group them in three arbitrary overlapping categories. The first group of factors are those evolving from *gross* group comparisons of the differences between males and females. Males and females are not the same. There are many differences between them. Although these sex differences are not as common and/or binding as some people seem to imply, some of the differences are fundamental (Sherman, 1971). Further, these differences cover a wide spectrum of dimensions, from purely biological to all psychological differences.

It is beyond the scope of this document to discuss the magnitude and validity of all such factors identified in the literature. However, all the factors identified within this category share two properties. First, they are factors that differentiate beween males and females yet may not be easily manipulated if differences

in opportunities for the two sexes are to be remedied. In other words, these basic differences have to be acknowledged in the implementation of any policy for change in the status of women in mathematics, yet themselves may not be altered. For this reason, these factors may be useful in a descriptive way to explain some aspects of the avoidance syndrome rather than in a prescriptive sense for its remediation. Secondly, it is not clear, at our present stage of knowledge, what is the impact of these differences on the disproportional representation (or achievement) of females in mathematics. However, many questions could be raised from this discussion for further investigations to reach a better understanding of problems that females face in mathematics.

The second category of factors that will be examined as possible causes of the avoidance syndrome, are *specific* group comparisons between males and females on dimensions directly related to the study of mathematics. These are factors related to attitudes toward mathematics and its study. The word "attitude" here is used in its most general sense to mean any affective (i.e. non-cognitive) force that causes an individual to approach or avoid a certain task. In contrast to the first category, the factors discussed here are amendable to manipulation and, consequently, could be directly challenged to remedy the avoidance of females to mathematics.

The last group of factors that may be crucial in causing the lack of interest of women in mathematical studies are related to *environmental* factors. Human beings do not function in a vacuum. Although the degree of social conditioning may be exaggerated, no one can deny the impact of society on both conscious and unconscious decisions on individual tasks. Furthermore, it has often been stressed that females and males are not raised in identical environments. In this section the specific aspect of the environment that is related to opportunities to pursue mathematics will be examined. Even though no single factor discussed may by itself be sufficient to explain (or remedy) the avoidance phenomenon, the possibility of differences in opportunities for males and females to learn mathematics cannot be ignored.

Intrinsic Differences Between the Sexes

One common misinterpretation of the word "equality" of the sexes is "sameness". The negation or underestimation of all differences between the sexes lead to error in understanding either sex and to disappointment in dealing with sexism. It is not clear to the author whether the zealous women fighting for their new identity or the chauvinistic male misreadings of the arguments presented by the feminists, that are responsible for this misinterpretation. The truth remains that the "myth" of sameness of the sexes does not stand up to the challenge from empirical research.

Two recent and extensive studies of the psychology of women (Bardwick, 1971 and Sherman, 1971) have dealt with the biological foundations of some psychological differences between females and males. Although the two authors do not always agree in terms of approach or conclusions, the message behind both works is that there are fundamental differences in the growth and maturity of males and females. Sherman concludes her study by noting that *"women begin life with cells that are fundamentally different from men. In the course of development, this causes anatomic differences and other differences as well,* (page 288). A similar conclusion is reached by Bardwick. It is a common practice in the field of psychology today to discuss the stages of development and maturity in terms of a series of crises that constitute the normal course of growth. *"At times, males and females may experience similar crises but, overall, the nature and timing of their sex-linked crises will tend to differ",* (Bardwick 1971, page 206).

It is a well established fact that males and females have different hormones and endocrines. The hormones control many physical and mental characteristics of the individual. There is some evidence that they may also influence the nervous system as well as temperament. Bardwick talks about limited evidence for a "female brain" and a "male brain", even at early stages of development. The importance of these differences in the central nervous system is that they determine to a certain extent the ability of children to cope with tasks appropriate to their age. For example, males possess characteristics such as greater size, high activity level, impulsiveness, genital sexuality and aggression that bring them into conflict with adults sooner than females. While males seem to fight for independence early, the highly verbal females choose other acceptable forms of aggression that do not challenge the authority of adults. Hence, *"compared with boys, there is a delay in a girl's development of an independent self",* (Bardwick 1971, page 207). It is irrelevant here to give a detailed account of the difference between females and males at each stage of development. A more detailed (non-technical) description of the development of men and women is given in Gail Sheehy's bestseller PASSAGES (1974).

However, before leaving this discussion, it is important to deal with one issue related to the implications of these basic biological/psychological sex differences. At the conclusion of their most extensive review of research on sex differences, after noting some biological differences between the sexes, Maccoby and Jacklin (1974) raised the question "Is Biology Destiny?". In other words, do these "fundamental differences" imply that females and males lead different lives, engage in different activities and hence, should be evaluated on different criteria? In short, are these differences to be regarded as justifications for sex roles and stereotypes? Disregarding the other factors that determine behaviour, it might appear that the answers to the above questions are in the affirmative. However, when social and cultural conditions are taken into consideration, this ceases to be the case. Sherman (1971) uses the following illustration. It is an established fact that males are superior to females in terms of

physical strength. In societies where physical strength is crucial for the survival of its members, it is clear that sex roles have to emerge in terms of activities requiring use of physical strength. However, as that society becomes more mechanized, it loses the justification for any differentiation between the sexes on that attribute. Hence, it is clear that social conditions may exaggerate or diminish the magnitude of sex differences. Consequently, biology is only a part of destiny.

Parallel to the above differences in biology and psychology of males and females, there are some "fairly well established" differences in the cognitive domain. Maccoby and Jacklin (1974) put the relative superiority of females in verbal ability and of males in spatial ability in this category. Fennema (1978) asserts that the male superiority in spatial skills is in one area of spatial visualization, which *"involves visual imagery of objects, movement of objects themselves, on changes in their properties"*, (page 9). Further, Sherman (1977) reviewed five different theories related to the biological sources of sex related differences in mathematics. Only one theory was judged as tentatively supported by empirical data; namely, the hypothesis that females and males have different spatial and verbal abilities as a result of differences in the two hemispheres of the brain. This factor, interacting with educational and social conditions may explain the above differences in achievement and avoidance. However, reinforcing the theme that biology is not destiny, Fennema (1978) points out that the evidence of the relationship of spatial ability to achievement in mathematics is not decisive. Although a logical connection could be shown between mathematical content and spatial visualization, results from empirical studies are not always consistent. *"Even less is known about the effect that differential spatial visualization has on mathematics learning of females and males"*, (page 11).

Differences in Motivation/Attitudes

In trying to explain the lack of achievement (when it exists) or participation of females in mathematics, one can raise three hypotheses regarding female motivation. Either females are not as highly motivated as males; females' achievement motivation is of a different nature to that of males; or females' achievement motivation is blocked by other factors external to motivation. Empirical evidence concerning only the first hypothesis is conclusive. Maccoby and Jacklin (1974) report that the claim that females lack achievement motivation is unfounded. In most studies reviewed, females scored as well as, if not better than males under "neutral" testing conditions. Males, however, tend to be more responsive to competitive situations than girls, but not necessarily to a higher level of achievement motivation.

With respect to the hypothesis of differential motivation of males and females Hoffman (1972) employs the concept of effectance motivation presented by White (1959). White realized the existence of many drives in human behaviour that are playful and exploratory in character, and at the same time reveal direction and selectivity and persistance. Such activities cannot be explained by usual primitive basic drives and appear to be self-motivated. White uses the form "effectance" to describe this motivation. Hoffman (1972) argues that because of differential experiences in child rearing, females develop different means to satisfy the effectance motivation from boys. While males achieve that motivation by mastery, the effectance of females is contingent on eliciting help from others. This hypothesis confirms the belief that females are trained to aim to "please". Hence, if the motivation to achieve is in conflict with effectance drive, that is attained by affiliation, one has to be sacrificed for the other or anxiety may result.

The last hypothesis explaining the lack of pursuit of girls to mathematical studies is the blockage of achievement motivation. Stein and Bailey (1973) note some inherent conflict between achievement motivation and feminine role performance. The characteristics that are logically associated with achievement, such as, independence, assertiveness, competitiveness and aggressiveness are in direct conflict with societal expectations of feminine behaviour. On similar lines, Horner (1972) discusses the concept of "fear of success" that inflicts many otherwise highly motivated women. The realization that achievement may cause negative consequences to the female as a result of certain societal expectations, tends to inhibit performance and lowers the level of aspiration of many females.

The discussion shall now turn to some important questions regarding the attitudes of males and females toward mathematics and its study. There are various issues that can be identified in this area. Four questions will be raised and relevant literature will be cited to attempt to answer them.

1. Are there sex-related differences in the enjoyment of mathematics?

   In a widely quoted study, Ernest (1975) reveals rather interesting results related to liking of males and females to the study of mathematics. Students from grade 2 to 12 in Californian schools were asked to rank four school subjects in the order of enjoyment. More males reported enjoying science and social science than females. More females reported enjoying English. However, mathematics was the only subject with no sex differences shown in preference. The distribution of both sexes on the various possible ranks were very similar. Although this result is rather interesting, and contrary to some common beliefs, it is not unique. Fennema and Sherman (1977(a), 1978) reported similar results. In a comprehensive instrument for measuring affective factors related to achievement in

mathematics, the authors included a measure for effectance motivation in mathematics. The importance of this measure stems from the hypothesis that females do not "naturally" enjoy problem solving activities as much as males. In all four high schools studied at Wisconsin, as well as four middle schools, there were no sex related differences on this measure. Boys did not reveal greater liking for mathematics than girls.

Other studies reviewed by Aiken (1970) confirm the above observation that girls in primary schools have at least the same enjoyment of mathematics as boys. However, research conducted by Aiken on University populations showed consistently more positive attitudes by boys for mathematics subjects. Similar results are reported by Hilton and Berglund (1977) in a longitudinal study using secondary school students. A possible explanation of this discrepancy between the university and lower levels students is the effect of differential social factors reinforcing the image of mathematics as a male domain. A second reason could be attributed to the span of ten to fifteen years separating Aiken - Hilton studies and Fennema - Sherman studies. Many social changes in the role of women have occurred during this span that may have narrowed the gap between the attitudes of males and females toward mathematics.

2. Are student attitudes related to achievement in mathematics?

The direct relationship between high positive attitudes and high level of achievement in any field of study appears to be common sense. In other words students enjoy what they do best and, conversely, they do best what they enjoy. However, in the field of mathematics this relationship is more apparent than real. In the international study of mathematics achievement reported in a previous chapter (Husen, 1967), the correlations between achievement and attitude, though positive and significant, were rather low. However this relationship is not sex free. Aiken (1970) points out that sex is an important moderating variable in predicting achievement from measures of attitudes. The prediction of success in mathematics for girls from attitudinal measures is better than that of boys.

However, just as achievement is not a sole predictor whether girls could study more mathematics, it is also true that attitudes are not sole predictors of girls continuing further studies in mathematics. In the studies by Fennema and Sherman, although girls said they enjoyed mathematics, and that mathematics was relevant to their own sex, fewer girls chose to study mathematics at grade 12. The authors noted that this was a fairly convincing case of the negative impact of certain sex roles on the election of mathematics subjects by capable female students.

Further interesting relations between attitude and achievement is reported by Preece (1979) in a British population. Students

from five comprehensive schools were given both achievement and attitude tests at the beginning and at the end of their second year. No sex differences were reported for either measure at both testing times. However, there was a noticeable drop in the attitude of girls at the end of the year that was not paralleled by a drop in achievement. The author concluded that this decline in attitude might account for the swing of girls away from mathematics in the coming years. The career teachers in the schools reinforced this hypothesis by reporting cases where more girls changed their preferred choices of careers because of mathematics requirements, in spite of the fact that their level of achievement in mathematics equalled that of boys.

3. Is mathematics seen as equally relevant by boys and girls?

There seems to be strong evidence supporting the conclusion that boys and girls in general, are not interested in pursuing the same fields of study. It is difficult to determine whether the reason is simply sex roles stereotyping and conditioning or whether there are more serious intrinsic differences in the interests of both sexes. However, it is an established fact that more mathematics is needed in every day life and in more careers and jobs. However, do females regard mathematics as being as relevant to them as it is to males?

The longitudinal study reported by Hilton and Berglund (1974) yield interesting insight on the question posed above. At grade 7 there were no differences between views of boys and girls regarding the relevance of mathematics to future careers. The same group tested 2 and 4 years later revealed significant differences favouring boys. This pattern presents another strong argument for the effect of social conditioning on the interest of girls in studying mathematics. It is logical to assume that the views of relevance of mathematics to careers and further study determines to a large extent whether an individual pursues further studies in mathematics or not. Empirical evidence supports this assumption. Fox (1976) reported a result by Haven showing that the best two predictors for the choice to take more mathematics were the relevance of mathematics to further studies and a larger interest in natural science compared with the social sciences. However, as Sherman and Fennema have argued, even though some girls consider mathematics as relevant to their sex as well as to boys, many fail to choose mathematics subjects at higher levels. This is due largely to social conditioning and pressures which will be discussed in the following section. However, there are other possible interpretations of this phenomenon. Aiken (1970) argued that mathematically able girls tend to reveal greater interest in natural sciences than less able girls. However, since girls in general tend to score higher than boys on social value measures compared to theoretical values, this creates an internal conflict between the abilities and values in high-ability

females, Fox (1976).

4. Are there sex related differences in confidence to study mathematics?

In the study reported by Anderson and others (1975) high school graduates were asked to predict their ability to handle higher level mathematics. More males than females were sure that they would be able to handle higher mathematics (46% compared with 25%). It is worthwhile noting that the mean performance of both groups on mathematics matriculation exams were identical. The same phenomena of girls underestimating their mathematical ability was noticed by Dornbusch (In Ernest, 1975). Students in that study were asked to give justification for obtaining poor marks in mathematics and other subjects. Most students gave the reason of a lack of effort for poor grades in all other subjects. There were no noticeable sex differences. When it came to mathematics, lack of ability was given by 26% of the girls and only 15% of boys. In some other minority groups tested in the state of California the ratio of girls to boys who gave this particular reason was 3 to 1.

According to Fennema and Sherman (1977(a), 1978) confidence in one's ability to learn mathematics constitutes a critical dimension to explain sex related performance in mathematics. The two distinct measures anxiety and confidence correlated very highly with each other so that for practical reasons they could be considered identical. That is, high anxiety implied low confidence and vice versa. In three of the four high schools studied and one of the four middle schools, girls were less confident in studying mathematics than boys. Further this dimension correlated rather highly with mathematical achievement (almost as high as verbal and spatial ability).

The question of mathematics anxiety needs to be examined more closely. We live in a mathematics anxious society. Suydam (1979) points out that *"as a society we have accepted fear and dislike for mathematics as normal"*. She adds *"specially for girls"*. In the introduction to her book Women in Mathematics, Lynn Osen states that, *"many women in our present culture value mathematical ignorance as if it were a social grace"*. The term Mathophobia, introduced by a prominent mathematician at Massachusettes Institute of Technology is becoming a part of our vocabulary. Phobia, according to Webster's Dictionary is *"an exaggerated usually inexplicable and illogical fear of an object or a group of objects"*. More specifically, Mathematics anxiety is an "I can't" syndrome, (Tobias, 1976). *"I can never do maths; I never understood maths; I do not have a logical mind; I can't deal with numbers"* and so on. Sovchik (1978) points out that there are disproportional numbers of mathematics-anxious females. The review by Sovchik suggests that sex related differences in reporting anxiety are minimal in primary years but girls tend to report greater anxiety at

later years. There are many ways of dealing with mathematical anxiety. Some of them will be dealt with in the following chapter.

Societal Factors

Society in this context is taken to mean any factor external to the individual learner or content that might affect learning. As such it includes school setting, teachers, homes, books, media and so on. It is safe to generalize that society traditionally has not expected girls to do well in mathematics or even do mathematics at all. Many educators and researchers have applied the term "a male domain" to describe mathematical endeavours (Burton 1979, Keeves 1973, Fennema and Sherman 1977(a), Widdup 1972). A girl venturing into a mathematics field is venturing into foreign and strange (not to say hostile) territory. Although no direct prohibitions exist today to keep girls away from mathematics, the indirect messages conveyed to girls to "keep out" are consistent and clear. The sad fact about these messages is that they are almost never intentional or with malice, yet nevertheless are destructive and limiting to the chances of girls pursuing their desires and living up to their potentials.

The negative messages to girls not to be very interested in mathematics start at home. It is not the intention here to document the differential rearing of boys into independent exploratory adults and of girls into conforming pleasing beings. For the purposes of this document, discussion will be restricted to those aspects at home that affect the study of mathematics. Hilton and Berglund (1974) reported that more boys than girls perceive both their mothers and fathers expectations as strongly favouring the children's continuation of high school studies. Similarly more boys said that they talk about science matters with their parents. The studies by Fennema and Sherman (1977(a), 1978) confirmed these observations. In two schools studied, boys perceived their father's and mother's encouragement for their children and value of mathematical talent in them more than girls. It is interesting to note that in these same schools boys achieved more on the ability tests than girls. Fennema and Sherman (1977(b)) evaluated the role of parents as follows:

> *"Parents perceive mathematics to be more appropriate for boys than for girls, and by their actions parents offer more encouragement to boys than to girls to learn mathematics. Parents report buying more mathematical games for boys ... and offering more explicit reward and reinforcement to their sons to learn mathematics than to their daughters ..."* (page 371).

The same conclusion was reached by Martin (1971) on Australian

families: *"parents tend to see the boys and girls participation in education as being different: boys more as future breadwinners and girls more as being protected and supported as housewives and mothers of the family"*. It is not surprising then that mathematics is seen more relevant to the former than the latter sex. However it is important to note that families do not only play a negative role in discouraging girls from mathematics but a very positive one in some instances. Analysing the bibliographics of many prominent females in the field of mathematics and related areas, shows that most of them came from families that valued intellectual activites with children (Burton 1979). Also, most of these women identified with a father who was supportive and encouraging of intellectual achievement by his daughters, (Ernest, 1975; Fox, 1976).

Next comes the peer pressure. The study reported by Ernest (1975) showed that students in the primary school tend to be competitive on the basis of sex. Each group asserted that they are better in mathematics than the other group. In the secondary school, both boys and girls thought that boys are better in mathematics. According to the questionnaire sent to teachers at those schools, primary school teachers agreed with the students on the superiority of boys. *"In the cases where male performance is found to be superior, we may be observing the so-called "Pygmalian effect" in education"* (page 10) concluded the author. In that group of teachers, almost all teachers expected their male students to do better and none expected their female students to do better in mathematics.

The differential treatment of males and females by teachers in mathematics classes goes beyond simple expectations. It often has been suspected that teachers do not deal with male and female students in the same manner in mathematics classes. In her doctoral dissertation, Joanne Becker (1979) furnishes some evidence concerning this differential treatment. The author found quantitative and qualitative differences in teachers behaviour with male and female students. Teachers were more likely to call on a male volunteer to answer questions than females. Higher order questions were asked twice more frequently to males as to females. More boys received encouragements and feedback and more teacher-initiated individual help. In a follow up interview some teachers seemed to think that boys need that encouragement more than girls to work up to their maximum potential.

Not only girls are not expected to do well in mathematics, they are sometimes penalized for doing so. Lunchin (1979) reports numerous complaints of women at all levels regarding differential treatment toward them in mathematics subjects. Not only at lower levels are "smart" girls viewed with suspicion. The same is true at the graduate level where girls have to work hard to prove their ability and interest in mathematics. No wonder then, when some women are faced with a choice between achievement in mathematics and social life, they sacrifice the former. The Lunchin study furnishes a further interesting result. A sample of women and men mathematicians members of the Association for Women in Mathematics

were asked to respond to the question *"what people or factors discouraged your decision to be a mathematician"*. One quarter of the males but one half of the females said that they had been discouraged by some person along the way. Sexist reasons were given by a fifth of the females and none of the males. A further 80% of the women recalled being treated differently because of their sex at at least one level of education. Only 9% of the men said the same.

The last example of social factors acting against the participation of women in mathematics that will be considered is the sexual stereotyping in many mathematics textbooks. There are two points to bring to attention in discussing this issue. Although there is some evidence that the problem context has a limited effect on the performance of girls in solving mathematical problems (Leder 1974; Preece 1979) it is not possible to generalize and blame the lack of achievement or participation of girls in mathematics solely on sexism in textbooks. Further, as Reyes (1979) warns, it is not the intention to shift blame for sexual stereotyping in mathematics to limited numbers of book publishers and authors. However, this issue supports the hypothesis that society at large does not expect girls to study mathematics.

Mathematics textbooks share the problems regarding sexism with other textbooks in spelling, reading, science and social sciences. Girls are portrayed as passive, boys as active. Girls shown in pictures sewing, mopping, baking and boys playing ball and riding bicycles. Girls are affectionate, easily frightened while boys are strong and never cry. In addition to all these problems, mathematics textbooks have traditionally omitted the mention of female mathematicians. Even important biographies of mathematicians have neglected the contribution of noted women mathematicians. No wonder very few students are aware of the existence of women mathematicians and of their contribution (Luchins, 1979). Thus the image of mathematics as a male domain is reinforced.

In two articles appraising the status of stereotyping in primary textbooks in mathematics in the United States, that appeared in the May 1977 issue of the Arithmetic Teacher, the authors reached different conclusions. Kuhnke reviewed two textbooks and showed positive responses from the publishers to critics of sex role stereotyping. Sex bias was almost eliminated in those two series. However, in a more carefully reported analysis, Kepner and Koehn concluded that sexism is still alive and very much in evidence in eight textbook series used in 1975. In an update analysis of two new editions of two series reviewed earlier and one new series, the authors noticed some change in traditional female roles but not in traditional male roles. However, in the new series more female mathematicians are identified. A greater use is made of sexually neutral language. Similarly more balanced number of pictures of boys and girls are noticed. This does not imply that textbooks used in Australia are following the same trend. Yet, this goes to show that consciousness-raising efforts and some political pressure on book publishing companies is effective in solving at least one problem in sexism in mathematics education.

Summary

This chapter has considered a host of different factors and forces that might influence the choice of females to reject further study in mathematics. The first category of factors considered the basic differences in the biological, psychological as well as cognitive domains of males and females. Although many of these factors are not known to be directly related to the learning of mathematics, yet when they interact with social conditions they may form the basis for many sex roles differentiation and stereotypes in studying mathematics. Hence, as pointed out above, these differences need not be the "destiny" of girls in mathematics. With proper considerations they can be overcome if the avoidance of mathematics by girls is to be remedied.

The second group of factors considered differences in motivation and attitudes of females toward achievement in and the study of mathematics. There seems to be very little evidence that females are less motivated in mathematics than males. However, the literature presents various hypotheses regarding why girls do not achieve the same potential as boys. The concepts of other motivations and/or external conditions conflicting with the achievement motivations were discussed. Although the evidence regarding these conflicts is not decisive, they constitute rather serious challenges to the practice of teaching of mathematics. These basic hindrances need to be removed if mathematics is to become more accessible to females. The two specific conflicts presented above were the affiliation motivation and social repercussions of high achievement in mathematics.

In terms of differences in attitudes toward mathematics, the review above appears to support the following conclusions:

1. females are not intrinsically less interested in the study of mathematics;

2. females decline in attitude toward mathematics at upper levels of schooling does not necessarily proceed from decline in achievement. On the contrary, it seems to cause the avoidance of mathematics and mathematics related careers;

3. females, in general, do not see mathematics as relevant to their aspirations for careers; and

4. females, in general, express greater anxiety and lower confidence in handling further mathematics subjects than males of comparable ability.

The last two factors appear to be of rather effective in causing females to participate in or avoid mathematical activites and studies.

The last category of factors discussed in this chapter are related

to external forces acting against the participation of women in mathematics. It has been argued that society at large seems to expect less of females in mathematics. Differential experiences starting at home and extending to peer relations as well as school settings often discourage girls from pursuing higher mathematics. All of these factors could be manipulated and indeed have to be changed, to solve the situation of lack of mathematical preparation of girls in mathematics. The next chapter will suggest means by which this change is possible.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The studies reviewed in the previous chapter 3 of this monograph constitute a selected sample of the numerous articles and publications reported in the literature dealing with issues of sex-related differences. A rather loose criteria was used in the choice of studies for review. In some instances the mere availability of the document determined its inclusion. As indicated in the opening chapter, it is not the intention of this publication to document the findings of research on sex-related differences in mathematics learning or to present a critical appraisal of such research. Other reviewers had done that successfully. Rather this monograph was aimed at evaluating the practices of the profession of teaching of mathematics in dealing with the two sexes based on conclusions from the literature. In particular, Chapter I raised the question *"Is there sexism in mathematics education"*. All the evidence presented from the various studies was directed at answering this question. Further, to get a better understanding of the term "sexism" an operational definition was adopted that includes situations in mathematics teaching which, when they exist, would imply sexism.

Sexism often takes the form of institutionalized practices and conditions. However, regarding the level of emotion with which people deal with this and related issues, it should be obvious that sexism is also an internalized individual attitude and/or commitment. In the author's judgement this type of sexism requires more careful and high priority attention. Unless all individuals in the society come to terms with the forces behind sexism in their own life, no change in law, facts or organization can bring forth the desired change. It is particularly for this reason that this monograph will stop short of presenting a "yes" or "no" answer to the question *"Is there sexism in mathematics education"*. The only desirable answer to this question is that which is based on an individually made evaluation. It is hoped that the evidence put forward above, as well as the readers' own experiences in teaching mathematics may be employed to reach such a decision. Maybe it is

in order to stress that this policy should not be interpreted as a desire to remain uncommitted or of fear of committment, or even to mean that the evidence from literature is not conclusive. Rather, it reflects the authors refusal to accept any pre-fabricated answers which usually do not go beyond the domain of knowledge and into the domain of action.

Based on the review of literature in the previous chapters of the monograph, the following conclusions are possible. It is hoped that these conclusions are useful in reaching an informed decision on the existence and manifestations of sexism in teaching mathematics.

Conclusion 1: The profession of teaching of mathematics is facing a challenge as a result of public apathy and students avoidance of mathematics.

Conclusion 2: Mathematics is needed for many careers and is a pre-requisite to many courses of higher education. A lack of mathematical knowledge is a "critical filter" for many jobs and higher positions.

Conclusion 3: Females in our society avoid mathematical studies and reveal anxiety in studying and using mathematics to a greater extent than males.

Conclusion 4: The changing patterns of employment of females indicates that mathematical training is of special importance for them.

Conclusion 5: Girls do not avoid mathematics because of their low achievement in the subject. Similarly, girls do not achieve less in mathematics simply because of lack of ability.

Conclusion 6: Sex related differences in achievement in mathematics are not always consistent or large in magnitude. There is an indication that these differences are less frequent in new studies compared to older studies. Further, variation in ability within a single sex are often large and imply that differences between sexes are not of significant practical value.

Conclusion 7: Although females are equally motivated to achieve as males, social conditions present other incentives for females to curtail and limit their achievement.

Conclusion 8: Although females tend to enjoy studying mathematics as much as males, they consistently lack confidence in its study and fail to regard mathematics as relevant to their future career aspirations.

Conclusion 9: Traditionally, society has not expected girls to pursue and achieve in mathematics to the same level as boys and in some instances present forces that act against such achievement or participation.

Conclusion 10: To summarize all the previous conclusions in one statement: *Girls need more mathematics and are capable of dealing with more mathematics than is currently available to them;* and, under the right conditions, change in the present situation of insufficient preparation of females in mathematics is possible.

The present chapter will consider the means by which changes in the present situation are possible.

A Model for Change

Regarding the seriousness of the problems that females face in studying mathematics and the complexity of the causes behind these problems, the question *"what does it require to bring about the desired change"* is indeed a challenging one. In the past few years the profession has experienced escalating voices of discontent about the preparation of females in mathematics. Attacks came from the feminists, sociologists as well as educators. Within the span of a decade, this discontent was responsible for some considerable changes. Probably the most basic accomplishment within the last few years has been the awareness of the problem by the mathematics community. Mathematics teachers and educators are realizing that a problem does exist concerning girls and mathematics. The overt manifestations of sexism are being disclosed and attacked. The formation of special caucuses and interest groups by most major professional organizations, the numerous sessions held at many conferences in mathematics education, and recent publications reflect the concern of the profession about this problem. However, this "consciousness raising" is but a first step in the right direction. Shirley Hill, the president of the National Council for Teachers of Mathematics (1979-1980) called the *"professional educators (to) ... make both individual and organizational commitment to the formidable task of assuring truly equal opportunity for girls and young women to achieve in mathematics"*, (In Judith Jacobs (Ed), 1978). The statement on Guidance/Counselling by the National Council for Teachers of Mathematics identifies the wider society that should be responsible to make mathematics more accessible to girls.

> *"Today more than ever before, the study and appreciation of mathematics are vital to the*

intellectual development of a society and to its scientific, industrial, technological and social progress. It is essential that teachers, counsellors, supervisors, educational administrators, parents, and the general public work together to provide the best mathematics education possible to all students, regardless of sex ....."

Hence what is needed to bring about the desired change is highly committed and orchestrated action on the part of all those involved in the decision making process in teaching mathematics. In the next section, some specific recommendations will be presented to each group of individuals identified above. The literature is rich in such recommendations that tend to be isolated, incoherent and insufficient. What seems to be missing is a theoretical model to be used in analysing the steps of needed action as well as in planning and carrying out this action. One such model is suggested by Grace Burton (1978).

There are various situations in life where the model presented by Burton could be applied: breaking a certain habit, solving a problem, inducing change of pattern of behaviour in self or in others. Consequently, any of these situations could be used to explain the model. The components of the model will be by taking the situation of the dealings of a psychiatrist with her/his patient. In order for any progress to happen in the treatment there are three basic requirements on the part of the psychiatrist. (The exact same model could be developed from the point of view of the patient). First, the psychiatrist should possess sufficient information about the problem, the patient, the methods of dealing with the patient, and so on. A treatment that is based on anything short of solid knowledge is subject to trial and error and is very risky. Secondly, a sufficient commitment on the part of the psychiatrist toward the concern of the patient is essential. The counsellor has to reveal sufficient trust in the patient and sympathy with his/her concern and hurt. Thirdly, with the sufficient knowledge and the proper feelings, only through long sessions of talking and doing can change be brought about.

Burton identifies three components needed to bring about change in any situation dealing with human beings. The three essential components are illustrated by the diagram below. The three parts of the diagram are best explained by the following quotation from the author.

"When one sets out to solve any significant problem, three separate components of the solution must be considered. One must have knowledge of the problem and its ramifications, one must get in touch with his or her feelings about the issues under consideration, and one must act in such a way as to bring about a solution (see Figure 1). To engage in

research, to read research completed by others, to exchange ideas with colleages and to formulate models, all these are important in establishing a knowledge base; they contribute to the component labelled Thinking."

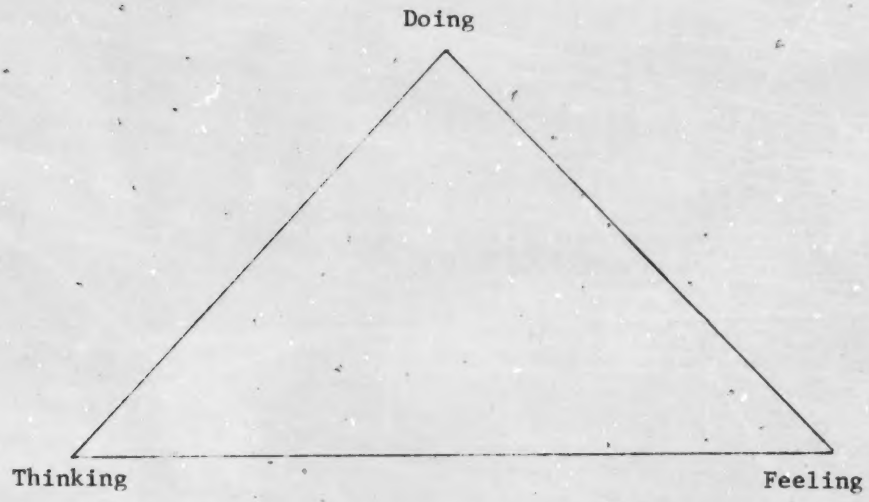


Figure 1. Components for producing change.

To become aware of one's "gut level" reaction to a situation, to vent one's anger or disgust, to form a firm resolve to do something about a distressing situation, all these responses are important to the Feeling dimension. But neither of these essential considerations will bring about change. Change is accomplished only by Doing. Library or laboratory investigations may be intriguing and sessions of "Poor me, I've been done ill by", may be a pleasant way to pass the time, but if the status quo is to be changed, a commitment to action and action itself, is essential." (Burton, 1978, page 36).

In her article, Burton goes on to give specific exercises that utilize the various components of the model to deal with the avoidance by girls of mathematics. Many of the recommendation are very sound and some will be included in the following section.

Recommendations

As argued above, females find themselves in an unfriendly environment when studying mathematics. Many aspects of society seem to act against the decision of girls to study mathematics. Throughout the monograph, the cultural/social forces were stressed as sources of alienation of girls from mathematics. Hence, to remedy the situation of females' lack of interest and knowledge in mathematics the whole social and educational structure must be prepared to accept some changes in attitude and expectations of girls in mathematics and related fields. The following is an attempt to illustrate some of these changes that are needed. Needless to say the list is not exhaustive. However, it does cover a wide spectrum of recommendations that are to be regarded as prototypes for lines of needed action. For convenience the recommendations are grouped according to the intended audience of those involved in the decision making process in teaching mathematics.

Family:

It is at home that a child normally starts experiencing sex roles. In this environment the child both observes the behaviour of adults of various sexes as well as receives direct messages about what is appropriate for their sex and what is not. There is also some evidence that the home can be a decisive force in unlearning sex roles that might have been acquired from peers or school. This necessitates a non-sexist child rearing, a topic that is beyond the purposes of this monograph. However, parents can contribute effectively to non sexist mathematical development of their children.

Some advice to parents:

1. Have faith in your daughters mathematical ability and whenever possible, take positive steps to enhance it.

2. Provide daughters with toys and games and activities that would develop their spatial and logical abilities, even if they are seen as "boy"-toys or games.

3. Realize that your daughters will live most of their lives in the twenty-first century, where societal conditions would be very different from your day and age. Never tell a daughter that she does not need to take mathematics because some day she will marry a husband who will take care of her needs. Remember that not all girls marry, some marry and divorce and some will have to work even though married. In any case they will need mathematics.

4. Realize that more careers are requiring mathematics background and that this trend will continue to increase. More jobs will be open to your daughters

if they have a good knowledge of mathematics.

Teachers:

Teachers could very well be the most decisive force in acquiring appropriate attitudes about mathematics and its study. Students have more contact with teachers than any other educational resource. While all other agents mentioned in this chapter have indirect contribution to the decision making process, teachers remain the final force responsible for implementing any change in the classrooms. The fact that many students look up to their teachers as models is very well established. Hence the following advice for teachers.

1. You have a right to feel good about your mathematical ability and ability to teach mathematics well. It is your responsibility to ensure that your attitudes are a model for your students. If you are not confident that they are a positive model, attempt to develop them in that direction by enlisting the help of other teachers, administrators or educators.

2. Never underestimate the ability of any single individual or have a preconceived idea about their pattern of behaviour based on your knowledge of the group that they belong to.

3. Never attempt to explain the performance of an individual on basis of their sex.

4. Provide role models for students of successful women in the field of mathematics and related professions. Invite appropriate successful women to talk to your students. Collect resources about mathematics and women, and mathematics and careers.

5. Keep an eye on sexism in textbooks or other resources. Bring it to the attention of your students, colleagues, administration and publishers.

6. Attempt to develop the confidence of girls in studying mathematics and their spatial ability. Increase the content of geometry in your teaching. Employ games such as Tangrams, map reading and other enjoyable tools.

Guidance Officers and Career Counsellors

At a period of unemployment, and a time of dissatisfaction by many people with their current jobs, the role of the guidance officer is becoming increasingly important. It is ample evidence that many girls are discouraged from doing mathematics either because of sex roles of society or the girls' previous achievement in mathematics.

However, boys of equal ability do not have to face the same pressure. The following advice is provided for those individuals counselling young people.

1. Realize that no job or profession in this day and age is not appropriate or open for an individual based on their sex. This will be even more true in the coming decade when students would be out in the workforce. Never limit the choice of students by discouraging them to drop mathematics if they are capable to study it.

2. Work in co-operation with the mathematics teacher to educate girls in the implications of high school decisions for the rest of their lives. Never assume that all girls will not need mathematics since they marry and raise a family. Never assume that a girl will not need mathematics in everyday life. Never give the impression that mathematics is a "male" domain.

3. Learn how to respond to the anxiety that girls face in studying mathematics. Females avoid mathematics for many reasons. Study these factors and be able to deal with them with the individual student.

4. Monitor career books and resources for sexist language.

Administrators:

There is evidence in the literature that indicates that sex differences are varied from one school to another. Although many factors may contribute to this phenomenon, the attitudes of school administrator to sexism in education may be an important contributing factor. Major policy changes in the education of females could not be accomplished without approval and support of school principals. Further, administrators have a commitment to provide the best possible education for all students regardless of sex. Hence, principals -

1. Provide human and financial resources to provide remedial help for females who are having difficulties in mathematics or who are not motivated in the field.

2. Monitor sexist practices in promotions in your school. Are the heads of department in mathematics always males? Are mathematics teachers in the upper grades all males?

3. Avoid any segregation of students in any activity on the basis of sex. Remember that such segregation only tends to reinforce sex roles and differences rather than present a better education for either sex.

4. Monitor the hidden curriculum in your school. Are there girls subjects and boys subjects? Are girls expected to behave differently from boys? Do girls have opportunity to be counselled by another female if needed?

Mathematics Educators/Researchers:

As any mathematics educator will testify, not all issues advocated by them necessarily reaches the classroom. However, the impact of the professional and mathematics educator on the introduction of major changes on the curriculum and practices of teaching mathematics should not be underestimated. Just as students use their teachers as models, so do teacher trainees use their instructors as models too. Hence the advice for the educators/researchers is:

1. As an educator you should be aware of what research really says about sex differences and what are the implications from this research. Remember that a little knowledge is a dangerous thing. Don't be over confident in your knowledge of sex differences and its implications. Monitor any sexist interpretations of the research.

2. Deal with the issues of sexism in your subjects. Allow each student to freely express their attitudes and get in touch with their feelings. Stress the relevance of mathematics to careers and employment.

3. Provide for the development of positive attitudes of students toward mathematics and its teaching.

4. Encourage professional organizations to create special groups that deal with problems related to girls and mathematics. Promote research studies as well as intervention programs that deal with these problems directly.

Society:

The educational system as well as the family are but two forces active within a larger domain which is the society or community. It is not within the scope of this document to analyse the interaction of the different bodies in the society to bring about change in behaviour or practices of the members of the community. However, society at large needs to be prepared and to accept the changes advocated by the education bodies. Hence, society needs to consider the following advice.

1. Do not hinder the activities of schools or individuals who are devoted to improve the teaching of mathematics for girls, by limiting funds for such studies and innovative programs.

2. Do not limit the choices of females in studying higher mathematics by looking down on high achieving girls or by discrimination in employment and promotion.

3. Do not pass legislation that limits the choices of students for careers by upholding sex roles and stereotypes and opposing counselling of girls and boys to consider non-traditional careers and professions.

Final Comments

At the conclusion of this endeavour, it is appropriate to attempt to anticipate some possible criticisms from suspecting readers about the importance of this study and its implications in particular, and about this line of research in general. Three main issues/ questions will be raised followed by the authors response to each.

1. Is the amount of time and expense devoted to such a project justifiable?

   The best answer to this criticism is to reiterate the three reasons that were presented in Chapter I as basic assumptions behind this analysis. The first reason is *educational*. It stems from the commitment of the educator and teacher to discover the nature of difficulties that students encounter in learning mathematics and their causes. This concern is exemplified in the developing area of diagnosis and remediation in mathematics. The results of the previous chapters indicate that females may be the largest single group of students with specific difficulties in learning mathematics. It has been shown that these difficulties are not necessarily cognitive, nevertheless they need attention and remedial consideration. Hence, the concern about sexism in mathematics education is in line with the aims of the profession of teaching of mathematics. Further, this concern is also in line with the generally acclaimed value system of the society and educational order that is based on equal opportunity for all members. This implies *moral* obligations on the part of the mathematics teacher to investigate why a group of students shy away from the field whenever they are given a chance. Lastly, in the present society where more women are engaged in the workforce, some out of financial necessity, there are *economic* reasons why this study, and similar ones, are very important. Every modern western society requires a certain amount of talent and skill in mathematics. Such a pool of talent cannot be restricted to half of the population without some repercussions on the welfare of society at large.

2. Are there practical implications for teaching of such a study?

By studying the factors that affect the learning and study of mathematics of certain population of students, a better understanding will be possible of how *all* students in general study and learn mathematics. Hence, the study of sex differences not only allow a better education for females, but also a better grasp of the numerous forces that affect the education of males and females in the field. It has been shown in Chapter II that the avoidance/anxiety syndrome is by no means restricted to the female sector of the school population. It is true that the elementary research of sex differences in achievement has lead to the consideration of "other factors" that affect the learning of mathematics. Such factors were previously assumed to apply but had not been directly investigated. Further, certain decisions in the classroom could be better made as a result of such reviews as the one carried out in this monograph. The grouping of students with mathematics classes is one such decision. The typical mathematics teacher is always seeking means by which grouping will influence the outcome of instruction. Does grouping by sex improve learning of mathematics? As a result of this study the answer to this question appears to be in the negative. Since variation in the ability of one sex is sometimes considerable compared to differences between the sexes, and since the distribution of abilities of both sexes tend to overlap, this means that some boys are weaker in mathematics than a typical girl and some girls are better in mathematics than a typical boy. Hence, segregation on the basis of sex does not serve any educational value and tends to exaggerate and reinforce sex stereotyping that limits the growth of the individuals of both sexes.

3. Is such an endeavour and analysis advocating sex role reversal and thus a challenge to the tradition of society?

Because of the delicate nature of the issues raised in this document, care has been exercised in the development of the arguments and statement of the conclusions. It is not expected, or intended, that this analysis will present major challenge to the organization of society. On the contrary, this endeavour was taken as a reflection on the profession of mathematics teaching of the new role and identity of the modern women. This document is to be seen as offering suggestions for change in the practice of teaching mathematics to cope with the changes in sex roles in society. In other words, it is a reaction from an educator to save mathematics from the public image it gained as a sexist field of study.

BIBLIOGRAPHY

Aiken, L. Attitudes Toward Mathematics, *Review of Educational Research*. Vol. 40, pp. 551 - 596, 1970.

Anderson, D. et al (Eds.). *A Study of non-metropolitan Colleges of Advanced Education in Australia*. Canberra: Australian National University, 1975.

Bardwick, J. *Psychology of Women: A Study of bio/cultural conflicts*. New York: Harper and Row, 1971.

Becker, J. Treatment of Students in Geometry Classes, *Women and Mathematics Education*. Newsletter of the Association for the promotion of Mathematics education for girls and women. Vol. II (1), 1979.

Bloom, L. and Bloom W. Who's afraid of Mathematics? - The Anxiety Syndrome, *Research in Mathematics Education in Australia*. Vol. II. Melbourne: Monash University, MERGA, 1977.

Board of Secondary School Studies, *Information Bulletin*. Vol. 8 (2), October 1978.

Bramley, G. and Ward, M. *The role of women in the Australian National University*. Canberra: ANU, 1976.

Bruner, J. *The Process of Education*. New York: Vintage Books, 1963.

Burton, G. Why Susie Can't - or Doesn't want to - Add. In *Perspective on Women and Mathematics*. J. Jacobs (Ed.). Columbus, Ohio: ERIC, 1798.

Burton, G. Regardless of Sex, *Mathematics Teacher*. Vol. 72 (4), pp. 261 - 270, 1979.

Carnegie Commission on Higher Education. *Opportunities for Women in high education*. McGraw Hill, 1973.

Cass, F.M. and Whither. A female profession, *The Australian Library Journal*. pp. 49 - 55, March 1973.

Clements, M.A. and Wattanawaha, N. Sex and age within grade differences in mathematical achievement of Victorian children, *Research in Mathematics Education*. Vol. 2, Victoria: Monash University, 1977.

Commission on Preservice Education of Teachers of Mathematics. *Guidelines for the Preparation of Teachers of Mathematics*. National Council of Teachers of Mathematics, USA, 1973.

Deem, R. *Women and Schooling*. London: Routledge and Kegan, 1978.

Department of Education, Queensland. *Information Statement*. No. 25, November, 1978.

Education Department, Queensland. *Education Abstracts* (No. 266), Employers test skills of school leavers. March 1979.

Ernest, J. *Mathematics and Sex*. Santa Barbra: Mathematics Department, University of California. 1975.

Fennema, E. Sex difference in Mathematics Achievement: A Review, *Journal for Research in Mathematics Education*. Vol. 5, p. 126 - 139, 1974.

Fennema, E. Mathematics, Spatial Ability and the Sexes. In E. Fennema (Ed.) *Mathematics Learning, what research says about sex difference*. Columbus, Ohio: ERIC, 1975.

Fennema, E. Sex-related differences in mathematics achievement: where and why? In J. Jacobs (Ed.) *Perspectives on women and mathematics*, Columbus, Ohio: ERIC, 1978.

Fennema, E. and Sherman, J. *Fennema-Sherman Mathematics Attitude Scale*. Journal Supplement Abstract Service, Vol. 6 (31), MS. 1225, Washington D.C.: American Psychological Association, 1976.

Fennema, E. and Sherman, J. Sex related differences in mathematics achievement, spatial visualization and sociolcultural factors, *American Educational Research Journal*. Vol. 14 (1), p. 51 - 71, 1977(a).

Fennema, E. and Sherman, J. Sexual stereotyping and mathematics learning, *Arithmetic Teacher*. Vol. 24, pp. 369 - 372, 1977(b).

Fennema, E. and Sherman, J. Sex related differences in mathematics achievement and related factors: A further Study, *Journal of Research in Mathematics Education*. Vol. 15, p. 189 - 203, 1978.

Fox, L. *Mathematically Precocious, Male or Female?* Columbus, Ohio: ERIC, 1976.

Fox, L. Women and Career relevance of Mathematics and Science, *Social Science and Mathematics*. Vol. LXXVI (4), pp. 347 - 353, 1976.

Hilton, T. and Berglund, G. Sex-differences in Mathematics Achievement - A longitudinal study, *Journal of Educational Research*. Vol. 67 (5), pp. 229 - 237, 1974.

Hoffman, L. Early Childhood Experiences and Women's Achievement Motives, *Journal of Social Issues*. Vol. 28 (2), pp. 129 - 155, 1972.

Horn, J. Human Abilities: A Review of Research and Theory in the early 1920's, *Annual Review of Psychology*. Vol. 27, pp. 437 - 486, 1976.

Horner, M. Achievement-related conflicts in Women, *Journal of Social Issues*. Vol. 28, pp. 157 - 175, 1972.

Husen, T. *International Study of Achievement in Mathematics*. New York: Wiley, 1967.

Irons, C. *An Investigation of Research and Practices in Clinical and Corrective Mathematics*. Brisbane: Department of Mathematics, Kelvin Grove College of Advanced Education, 1978.

Keever, J. Difference between the sexes in mathematics and science courses, *International Review of Education*. Vol. 19 (1), pp. 47 - 62, 1973.

Kepner, H. and Koehn, L. Sex Roles in Mathematics: A Study of the states of Sex Stereotyping in Elementary Mathematics texts, *Arithmetic Teacher*. Vol. 24, pp. 379 - 385, 1977.

Kirk, R. *Experimental Design: Procedures for the Behavioural Science*. Bemont, California: Brooks/Cole Publishing Company, 1968.

Krutetskii, V. *The Psychology of Mathematical Abilities in school children*. Chicago: University of Chicago Press, 1976.

Kuhnke, H. Update on sex-role stereotyping in Elementary Mathematics textbooks, *Arithmetic Teacher*. Vol. 24, pp. 373 - 379, 1977.

Leder, G. Sex differences in Mathematics: Problem Appeal as a function of problem Context, *Journal of Educational Research*. Vol. 67 (8), pp. 351 - 353, 1974.

Lunchins, E. "Sex differences in Mathematics: How not to deal with them." *American Mathematical Monthly*. Vol. 86 (3), pp. 161 - 168, March 1979.

Maccoby, E. and Jacklin, C. *The Psychology of Sex Differences*. Stanford: Stanford University Press, 1974.

Martin, J. Sex differences in Educational Qualifications, *Melbourne Studies in Education*. Melbourne: Melbourne University Press, 1972.

Mathematical Association of America. *Careers in Mathematics: many paths are open*. Pamphlet. Washington D.C.: MAA, not dated.

Mathematical Association of America. *The Maths in High School you'll need for College*. Pamphlet. Washington D.C.: MAA, 1978.

Mckinnon, K. *Girls, School and Society*. Canberra School Commission, 1975.

Osen, L. *Women in Mathematics*. Cambridge: MIT Press, 1974.

Perl, T. "The Ladies' Diary on Woman's Almanack, 1704 - 1841", *Historia Mathematica*. Vol. 6 (1), pp. 36 - 53, February 1979.

Preece, M. Mathematics: The Unpredictability of Girls, *Mathematics Teaching*. No. 87, pp. 27 - 29, 1979.

Reyes, L. Sexual Stereotyping in Mathematics: Beyond Textbooks, *Arithmetic Teacher*. Vol. 26 (8), pp. 25 - 26, 1979.

Roark, A. "Mathematics: Fundamental Changes Ahead". *The Chronicle of Higher Education*. May 15, pp. 3 - 4, 1978.

Schonberger, A. Are mathematics problems a problem for women and girls? In J. Jacobs (Ed.) *Perspectives on Women and Mathematics*. Columbus, Ohio: ERIC, 1978.

Sells,L. High School Mathematics as a critical filter in the Job Market, In *Wellesley - Wesleyan Training Program*. Massachusets: Wesleyan University, 1979.

Sheehy, G. *Passages: Predictable Crises of Adult Life*. New York Dutton, 1976.

Sherman, J. *On the Psychology of Women: A Survey of Empirical Studies.* Springfield, Illinois: Charles Thomas, 1971.

Sherman, J. *Summary of effects of Biological factors on sex-related differences in mathematics achievement.* Paper presented at the Annual Meeting of the American Educational Research Association. New York, 1977.

Sherman, J. and Fennema, E. The Study of Mathematics by high school girls and boys: Related Variables, *American Educational Research Journal.* Vol. 14 (2), pp. 159 - 168, 1977.

Souchik, R. *Anxiety and Mathematics Learning: A selected Review of the Research and Suggested Implications.* Paper presented at Fifth National Conference of Diagnostic and Prescriptive Mathematics. Arizona State University, 1978.

Squire, B. *Diagnosis and Planning for Remediation for Preservice Trainees.* Paper presented at Third Biennial Conference of Mathematics Education Lecturers Association, Armidale College of Advanced Education, 1979.

Stein, A. and Bailey, M. The socialization of achievement orientation in females, *Psychological Bulletin.* Vol. 80, pp. 345 - 366, 1973.

Suydam, M. A case for a comprehensive Mathematics Curriculum, *Arithmetic Teacher.* Vol. 26 (6), pp. 10 - 11, 1979.

Tobias. Math Anxiety, *Ms. Magazine.* September 1976.

Tuddenham, R. Intelligence, *Encyclopedia of Educational Research.* Fourth Edition, American Educational Research Association, pp. 654 - 667, 1969.

Wellesley - Wesleyan Training Program. Massachusets: Wesleyan University, 1979.

White, R. Motivation reconsidered: The concept of competence motivation, *Psychological Review.* Vol. 66, pp. 297 - 333, 1959.

Widdup, D. *The great Mathematical Inequality.* Unpublished Diploma of Education Thesis. University of Tasmania, 1972.

Young, D.C. (Ed.) *Queensland Tertiary Courses.* Brisbane: Printer Simpson Halligan and Sons, 1979.